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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER

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NOVEMBRE 1926

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IMPRIMERIE BIANCO LUNO

# Hydrography, Climate and Fisheries in the Transition Area

by

**Otto Pettersson.**

The Transition Area comprises, according to the definition of the International Council of the 4th of Sept. 1925, the region between Hanstholmen and Lindesnæs in the West and Bornholm in the East, that is to say, Skagerak, Kattegat, the Danish straits, the Belt Sea and the Arcona basin. The most interesting part thereof, from the hydrographical point of view, is the Kattegat channel with the Great Belt, the connecting joint between the Ocean and the Baltic through which the surplus of the river-water from Scandinavia and from a part of North and Central Europe is brought to the Atlantic as a surface current, while the salt water from the ocean flows in as an under-current into the Baltic.

On both sides of the Kattegat channel there is a number of Danish and Swedish light-ships from which daily observations of salinity, temperature, direction and speed of currents are made. These observations, which have been going on for 40 years, have enabled one to calculate the magnitude of the exchange of water that takes place between the Baltic and the Ocean.

The water flowing out yearly from the Baltic is estimated to be about 480 cubic kilometers[1]) and is distributed among the different months of the year as follows:—

[1]) R. Witting: Hafsytan, Geoidytan och Landhöjningen. Fennia 39, No. 5, p. 123 (1918).

M. Knudsen: Beretning fra Kommissionen for Undersøgelser af Danske Farvande, Bd. 2, Hefte 2, p. 60 (1899), has calculated the yearly outflow of the Baltic to be 450 cubic kilometers.

J. P. Jacobsen: Die Wasserumsetzung durch den Öresund, den Grossen und den Kleinen Belt. Meddelelser fra Kommissionen for Havundersøgelser, Ser. Hydrografi, Bind II, No. 9 (1925).

| January | February | March | April | May | June |
|---|---|---|---|---|---|
| 20,5 km³. | 54,5 km³. | 75 km³. | 59,8 km³. | 779 km³. | 43,9 km³ |

| July | August | September | October | November | December |
|---|---|---|---|---|---|
| 11,7 km³. | 37,1 km³. | 55,6 km³. | 32,2 km³. | 5,2 km³. | 16,2 km³. |

The salt water entering the Baltic with the under-current has its origin partly from the North Sea and partly from the Norwegian Sea. The former follows the Jutland Bank, the latter flows in from the north through the Norwegian channel. The water from the Atlantic itself, with over 35 $^0/_{00}$ of salinity, penetrates also over the north part of the North Sea plateau into the Skagerak and fills up its deep basin, but comes out towards the bottom of the sea at the northern entrance of the Kattegat channel and enters therefore somewhat mixed into the Baltic.

The under-current in the Kattegat therefore is not formed of Atlantic water but either of North Sea water or of water from the Norwegian Sea. With the North Sea water enter the more southerly fish-species, as for instance mackerel, whiting, hake and autumn spawning herring from the North Sea banks and, as rarer guests, a few fish-species from the Bay of Biscay and the Mediterranean, that have come into the North Sea from the Atlantic. With the water from the Norwegian Sea come also boreal fish-species like leng, and spring-spawning hering.

It has already for 55 years been observed that these "north-fishes" arrived in winter and spring and the "south-fishes" in autumn[1]). There is consequently a yearly period of these fish migrations which was explained when it was discovered that there existed a yearly periodicity, corresponding with it, of the oceanic water circulation[2]), — a periodicity which is nowhere so clearly marked as in the Transition Area. It has been characterized by the Swedish scientists as the *Systole* and *Diastole* of the sea of which the pulse-beat makes itself most clearly felt in the variations of the under-current in the Kattegat channel[3]).

This periodicity depends on cosmic causes and is produced by the variations in gravitation caused by the position of the earth relatively

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[1]) Möbius und Heincke: Die Fische der Ostsee. Berichte der Commission zur Untersuchung der Deutschen Meere 1877—1881 (II) p. 278.

[2]) O. Pettersson och Gustaf Ekman: Grunddragen af Skageracks och Kattegats hydrografi, K. Svenska Vetenskapsakademiens Handlingar, Band 24, No. 11 (1891).

[3]) P. F. Cleve, G. Ekman och O. Pettersson: Les variations annuelles dans l'eau de surface de l'océan Atlantique, Göteborg 1899.

to the sun and the moon, that is to say by tidal forces. There have been found in the current-system of the Kattegat tidal periods of daily, half-daily, monthly, yearly and secular period — both in the surface-current and in the under-current.

The surface-current, the so-called Baltic current, is formed by the outflow from the Baltic which spreads itself as a thin surface layer over the Skagerak and the Norwegian channel. This layer of low salinity water checks the tide on the surface of the sea, so that in all the Transition Area, from Lindesnæs to the interior of the Baltic, the ebb and flood on the surface of the sea is insignificant. This is all the more extraordinary as the tidal waves in the south of the North Sea and on the west coast of Denmark attain a height of 2 to 3 metres, while opposite Jutland, near Lindesnæs on the Norwegian coast, the amplitude of the tidal wave is = 0.

One has tried to explain this on the assumption that there is to the south west of Lindesnæs a so-called amphidromic point where the wave penetrating into the North Sea through the Channel interferes with the wave entering round the north of Scotland.

POINCARÉ states:

"Le concours de ces deux ondes donne naissance dans la mer du Nord à une région amphidromique située à l'ouverture du Skagerak; un autre point amphidromique se trouve également formé plus au Sud entre la Hollande et l'Angleterre."[1])

The correct explanation seems to be that the tidal wave coming from the Atlantic dips under the water layer of the Baltic current at the entrance to the Skagerak and continues as an internal tidal wave towards the east through the Skagerak and the Kattegat channel in the boundary layer between the surface-current and the under-current. The trough of the tidal wave on its arrival at the border of the Baltic current is filled by the outflow of the light Baltic surface water. When afterwards the crest of the wave of the flood tide arrives, the layer of the surface water thins out and spreads over the surface of the sea. The vertical movement of the tide-water is thus changed into a horizontal contraction and expansion of the thin layer of the surface water.

Under this the tidal waves propagate themselves as under-current or internal waves with a reduced speed and an increased amplitude according to STOKES's theory.

In these internal wave-movements in the sea all periods appertaining to the original tide-water are found again, and it is worthy of remark,

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[1]) H. POINCARÉ: Leçons de Mécanique Céleste, Tom. II, 2de Partie, p. 400 (1909).

that certain of these periods, belonging to the parallactic tide-water, which depends, not on the influence of the sun and the moon on the hydrosphere of the rotating earth, but on the position of the sun and the moon relatively to the earth, appear more clearly in the middle layers of the sea than on the surface, where the waves of the daily and half-daily periods (O. K., M. K.) dominate to such an extent that the parallactic waves become imperceptible (Mm. Mf. Ssa.) and can only be detected and measured by the calculation of long series of observations. Of these long-period parallactic tidal waves on the surface one has been able to detect in the North Sea region and in the Transition Area a yearly flood-wave from the ocean which culminates in October-December, when the water mark is at its highest, and has its yearly ebb-time in April-May when the water mark is at its lowest both on the coasts of the North Sea and of the Baltic (fig. 1).

In the middle layers of the sea these long-period wave-movements appear with the greatest clearness as internal waves of large amplitude, while the half-daily and the daily waves are damped and disappear through the influence of internal friction and usually only appear as under-water breakers against the coast-bank. Such internal flood-waves of half-daily period with an amplitude of about 3 metres have been observed at the entrance of the Great Belt[1]). Each time such a flood-wave in the boundary layer of the under-current (abt. 16 metres under the surface of the sea) penetrates into the Great Belt, the surface current is delayed or stopped until, 6 hours afterwards, the ebb appears in the boundary surface. Then the outflow of the Baltic water is accelerated up to 1 meter per second or even more.

While these powerful changes of level occur in the boundary layer of the under-current, and the surface-current in the strait alters its direction and speed, only a small ebb and flood is observed in the surface of the sea itself which reaches at the utmost ca. 30 cm. while the internal flood-wave in a depth of 16 metres raises and lowers its crest more than 3 metres. If there were not the protecting layer of surface-water checking, through its alternating retardation and acceleration in a horizontal direction, the influence on the sea-surface of the crests and troughs of the internal flood-waves, the flood-waves from the North Sea would twice a day inundate the lowlying coast of the Danish Isles and of Scania.

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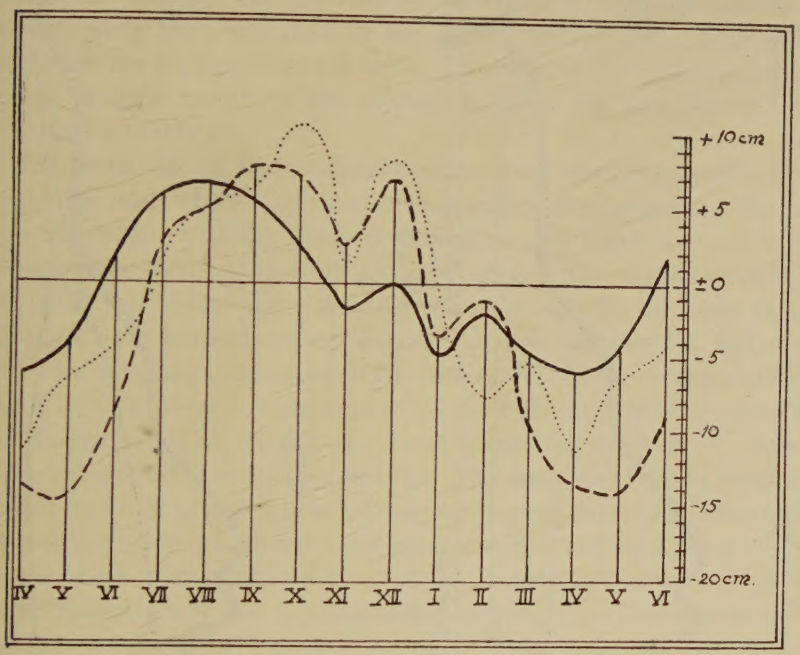
[1]) O. Pettersson: Ström-studier vid Östersjöns portar. Svenska Hydrografisk Biologiska Kommissionens Skrifter, Häfte III.

G. Ridderstad, ibid.

J. P. Jacobsen: Beitrag zur Hydrographie der Dänischen Gewässer. Meddelelser fra Kommissionen for Havundersøgelser, Ser. Hydrografi Bd. II, No. 2, p. 83 o. 84.

The parallactic tidal waves of $^1/_2$ month's, one month's and one year's period in the middle layer of the Kattegat channel reach a much larger amplitude than 2—3 metres. Accordingly the under-current in the Kattegat does not flow continuously as a stream at the bottom of the sea but in cascades, in a series of large internal billows, the course of which can be followed through the channel of the Kattegat by means




Yearly period of waterlevel.

——— at the German coast of the Baltic
– – – – at the Swedish coast of the Baltic
..... at the Dutch coast of the North sea

Fig. 1.

of hydrographical soundings from light-ships and by current-measurements with the registering apparatus prepared by G. Ekman and O. and H. Pettersson[1]). The following longitudinal sections through the Kattegat show certain characteristic variations of the under-current specially in the extreme northerly part of the Kattegat channel.

[1]) Svenska Hydrografisk Biologiska Kommissionens Skrifter, Häfte V.

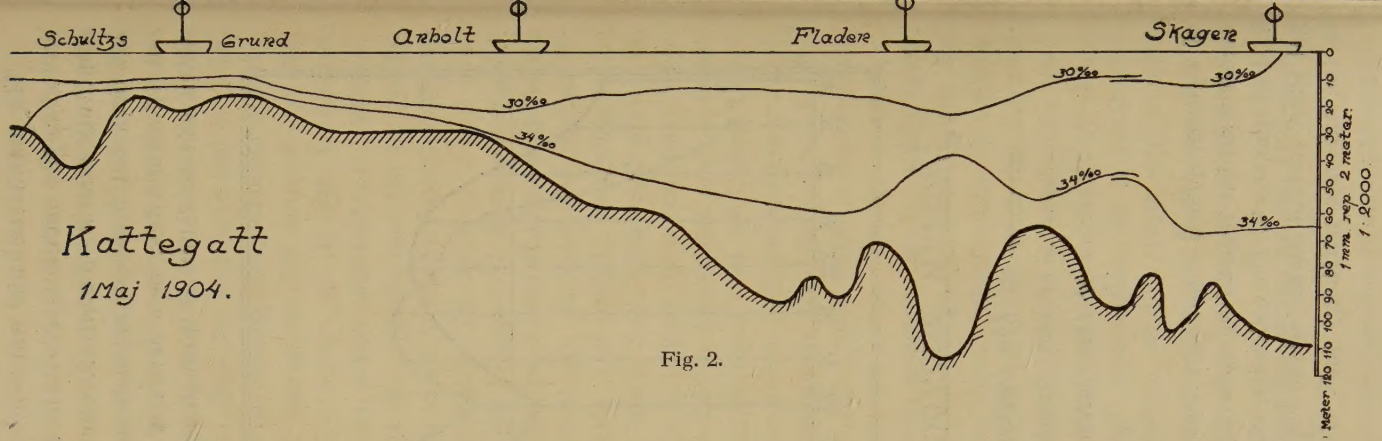

Schultzs Grund
Anholt
Fladen
Skagen
30‰
34‰
Kattegatt
1 Maj 1904.
1 mm repr. 2 meter.
1 : 2000
Meter

Fig. 2.

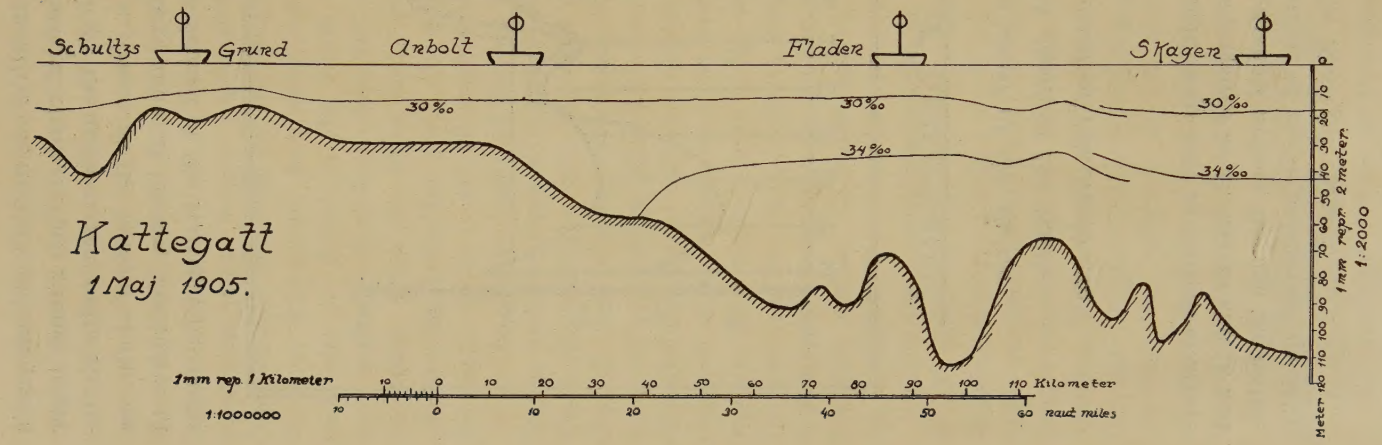

Schultzs Grund
Anholt
Fladen
Skagen
30‰
34‰
Kattegatt
1 Maj 1905.
1 mm repr. 2 meter.
1 : 2000
Meter
1 mm repr. 1 Kilometer
1 : 1000000
Kilometer
naut. miles

Fig. 3.

In every synoptic study of a large area such vertical changes in the shape of billows show themselves in the limiting surfaces of the different water-layers which mark the boundary of the waves of the under-water, — which in the present case are on their way south (see sections from May 1904 and 1905). The under-current in May is formed of North Sea water of 34 $^0/_{00}$, which isohaline can be considered as indicating its highest limiting surface. The 30 $^0/_{00}$ isohaline indicates approximately the lower limit of the surface-current. The water layers in between are formed of mixed water, a product of the intensive mixing process brought about by the friction between the entering and the outgoing current[1]).

The amplitude of these internal tidal waves which are produced in the middle layer of the sea, as also their speed of propagation, depends upon the density and the depth of the higher and lower layer of water, in conformity with the formula given by Stokes. The speed of propagation being in the first place determined by the depth, the wave in the boundary layer proceeds slowly over the shallow parts of the Kattegat. Such a wave having penetrated on the 26th of Oct. 1898 into the Kattegat took 6 days to cover the distance of 34 nautical miles between the two Danish light-ships at Skagen and Læsö Rende on the Aalbæk plateau with a speed of 0.118 metres per second[2]). The calculated time by Stokes's formula was 6 days and 4 hours. Over the deepest parts of the Kattegat channel the wave proceeded with greater speed and was observed on the 4th of November (after 9 days) at the Anholt light-ship, and on the 7th of November at the Lappegrunden light-ship in Öresund after 12 days. It is however seldom that an under-water wave can be followed by means of light-ship observations all through the Kattegat channel. As a rule the motion of the internal wave is checked by friction already in the outermost part of the Kattegat (see sections page 310). The wave-front naturally advances considerably quicker than the water stream. According to M. Knudsen a water-particle of the under-current takes 2 to 3 months to come from Skagen to Schulz Grund, which lies at the mouth of the Great Belt.

[1]) The effect is so powerful, that the greatest part of the salt water which enters into the Kattegat channel from the Skagerak as under-current is mixed up with the out-flowing water and moves with the Baltic current. According to M. Knudsen's calculation it is only a seventh part of the original flowing-in ocean water which finally reaches the Baltic. (Martin Knudsen: Ein Hydrographischer Lehrsatz. Ann. d. Hydrographie 1900).

[2]) O. Pettersson: Über die Wahrscheinlichkeit von periodischen und unperiodischen Schwankungen in dem atlantischen Strome etc. Svenska Hydrografisk Biologiska Kommissionens Skrifter Heft II, p. 23—24.

The wave-front passing through the Kattegat causes in the fjords off the Swedish coast oscillations, in the level of the bottom layer, of considerable amplitude. The level of the sea-surface being only little changed, the surface water in the fjord must stream out when the deep water outside the fjord rises to a higher level, and stream in again when the ebb begins in the deep water.

This effect in the fjords of the movements of the internal ocean tides in the Skagerak and Kattegat has been studied during a long run of years at the Swedish hydrographical station Bornö which is situated in the biggest and deepest fjord of Bohuslän, the Gullmar fjord. The position is particularly favourable because the tide on the surface is so unimportant that it does not conceal the powerful rhythmical movements which occur in the deep and can be automatically measured with registering apparatus, their character of a parallactic internal tidal phenomenon of monthly and yearly period having been thus determined. In the "Svenska Hydrografisk Biologiska Kommissionens Skrifter" there are series of such under-water waves represented. From a more recent work[1]) I extract a graphic representation of such waves, which appeared in Sept. 1922 at the constellation of the moon's nodapside, which happened at the autumnal equinox of that year, and brought about a variation in the tidal force which is represented in the following diagram. The relation between the variation of the force of the flood and the constellations of the moon and the internal changes of level in the deep water of the fjord is also shown in the diagram on p. 313.

The diagram contains also underneath a row of figures showing the quantity of herring taken during the autumn of the same year. There is in fact a connection between the yearly flood period of the ocean, which begins in September at the equinox with a series of big internal waves culminating in November, and the yearly period of herring-fishing in the Skagerak. Those waves have a $^1/_4$ yearly and a $^1/_2$ monthly period. The herring shoals following with the under-current seem to come in greatest quantities during the autumn and winter weeks when the internal movements in the sea are strongest. The herring-fishery is thus closely connected with the yearly hydrographical changes (the oceanic flood period during autumn and winter) like the mackerel-fishery which is related with the ebb period occurring in summer[2]).

The herring-fishery is also subjected to a longer secular periodicity

[1]) O. Pettersson: Innere Bewegungen in den Zwischenschichten des Meeres und der Atmosphäre, Acta Reg. Soc. Scientiarum Upsaliensis, Ser. IV, Vol. 6, No. 2 (1923).

[2]) See diagram of the change of the water mark, fig. 1 pag. 309.

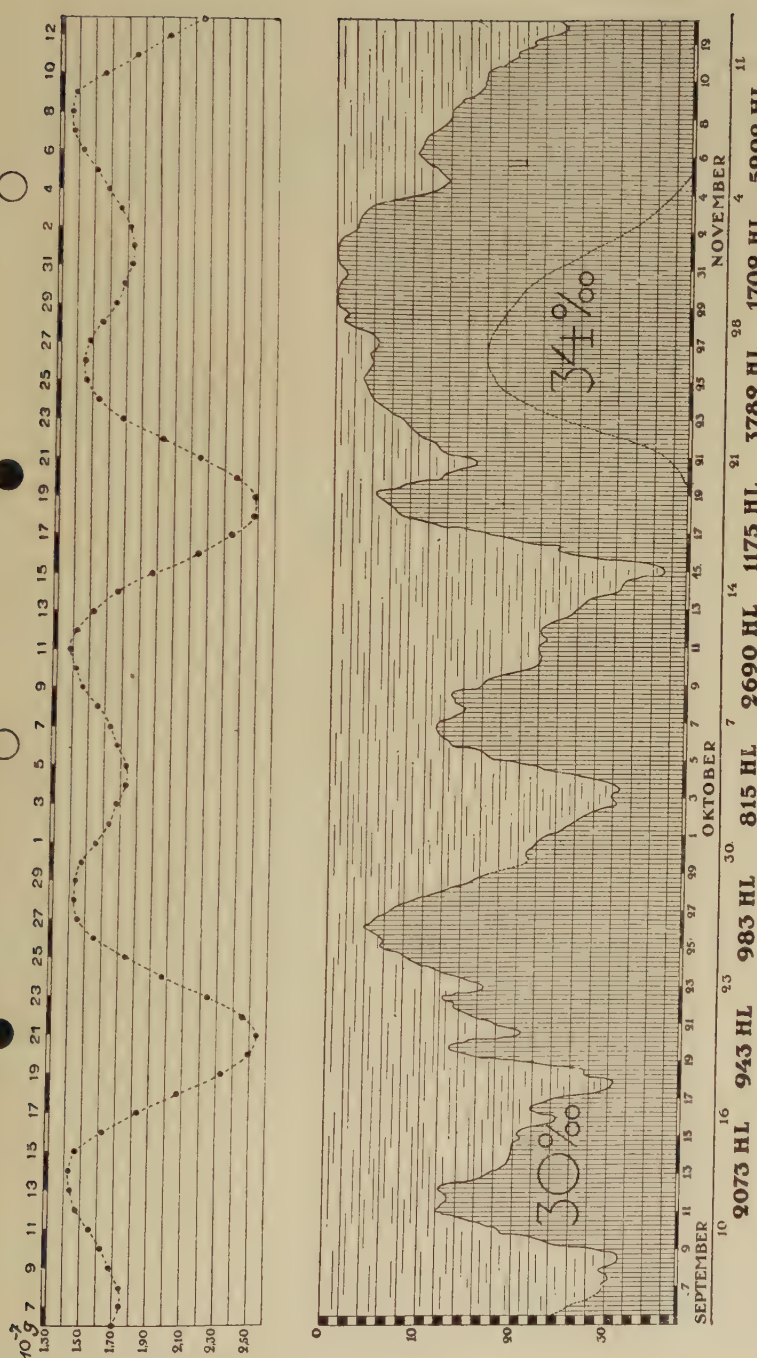

10⁻⁷ g
1.30
1.50
1.70
1.90
2.10
2.30
2.50
0
10
90
30
30‰
34‰
SEPTEMBER
OKTOBER
NOVEMBER
2073 HL
943 HL
983 HL
815 HL
2690 HL
1175 HL
3782 HL
1702 HL
5902 HL

Fig. 4.

known for a thousand years, which also depends on cosmic causes, i. e. the variation of the tidal force[1]) and has a period of 111 years. This periodicity shows itself as follows: during each century from 971 A. D. to the present time there has occurred a period of rich herring-fishing which lasted alternately abt. 20 to 30 and 50 to 70 years (big and small herring-fishing periods). These periods occurred thus[2]):

| Centuries | Periods |
|---|---|
| XIX | 1875—1896 |
| XVIII | 1752—1810 |
| XVII | 1660—1680 |
| XVI | 1556—1587 |
| XV | 1419—1474 |
| XIV | 1307—1362 |
| XIII | 1195—1250 |
| XII | 1083—1138 |
| XI | 971—1026 |

The longest of these herring-fishing periods were those which occurred in the XIIth, the XIVth and the XVth centuries when the constellation called nodapside of the orbit of the moon approached the time of the position of the winter-sun (Solstice) and the perihelium of the earth, which occurred in the beginning of the fifteenth century (perihelium-nodapside) when the strength of the flood (now and then) reached its absolute maximum[3]). This caused intensive movements in the middle layers of the sea, which led the herring-shoals farther towards the south than in our time, that is up to Öresund, where the big Hanseatic Herring-fishery occurred during the last centuries of the Middle Ages. This came to an end in the 17th century. In our times when the nodapside of the moon's orbit, which has a retrograde movement in the ecliptic, occurs earlier in the year (that is in September) the strength of the flood does not reach such high values and the influx of the herring in the Transition Area now stops at the outside part of the Kattegat channel, between Varberg and Skagen when it is at its best.

The last big herring-fishing period started in 1875 and closed in the winter of 1896. The hydrographical conditions that caused the cessa-

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[1]) O. Pettersson: Étude sur les mouvements internes dans la mer et dans l'air. Svenska Hydrografisk Biologiska Kommissionens Skrifter, Häfte VII.

[2]) A. W. Ljungman: Nordisk Tidsskrift for Fiskeri 1879. Köbenhavn.

[3]) O. Pettersson: Étude sur les mouvements internes dans la mer et dans l'air. Svenska Hydrografisk Biologiska Kommissionens Skrifter, Häfte VII.

tion of the herring-fishery are well known[1]). The reason was that the waters of the Atlantic current flowed with unusual strength over the north part of the North Sea in November 1896 and the following months and filled up the Norwegian channel, so that the inflow of water from the Norwegian Sea and partly also from the north part of the North Sea to the Skagerak was checked. During the preceding herring-fishing period the inflow of "sterile" Atlantic water had been small, consequently the entrance to the Skagerak had been open to the waters of the North Sea and of the Norwegian Sea and to the herring-shoals which jointly penetrated therefrom. This meant a considerable diminution of the winter herring-fishery on the west coast of Norway, during the Swedish herring-fishing period from 1875 to 1896. Afterwards the Norwegian herring-fishery soon increased to its former importance. During the secular herring-fishing periods in the Skagerak an alternation therefore takes place between the Norwegian and the Swedish herring-fishery. This alternation has been known for two centuries, but the cause of it has only been explained by the recent hydrographical researches.

The light-ships stationed in the Kattegat have to be with-drawn during certain cold winters for a few weeks or months on account of the drift-ice which is formed in the southern and central Kattegat and is driven out with the surface current into the Skagerak where it melts in the salter and warmer sea-water. The ice in the Kattegat is formed partly in the fjords and near the shore, and partly it appears as the so-called "pancake-ice", that is to say in the form of discs shaped like plates, suddenly rising from the deep. It then fills up the sea for miles around with a layer of loose but dense closely packed ice-lumps which hinder all sea-traffic and fishing. During the severe winter in 1879 Gustaf Ekman[2]) was able to ascertain the conditions of the formation of pancake-ice in the Kattegat. During cold and quiet weather, the surface layer in the Kattegat of 26 ‰ to 29 ‰ salinity can be cooled down to —1° C. without ice being formed. If afterwards a fresh water-layer of 16 ‰ to 22 ‰ salinity from the current glides over the salt and cold water, the formation of ice can be suddenly produced in the boundary surface, while the lower cold water-layer, which on account of its high salinity cannot freeze, absorbs the latent heat developed during ice formation in the boundary surface under the upper layer. In February 1879 such an ice-formation occurred at abt. 8 metres deep

[1]) G. Ekman, J. Hjort, P. T. Cleve, O. Pettersson, Skageraks tillstånd under den nuvaranda sillfiskeperioden. Göteborg 1897.

[2]) Grunddragen af Skageraks och Kattegats Hydrografi, p. 122.

under the surface. In the night of the 26th February the sea was in the morning, as far as one could see from the position of the farthest light-house[1]), covered with a thick layer of ice-lumps.

The formation of ice in the Kattegat has after-effects[2]) on the temperature of the under-current during the spring following a severe ice-winter. A severe atmospheric period of cold has some influence on the North Sea surface-water that afterwards enters into the Skagerak and forms the under-current in the Kattegat, which there during spring after an ice-winter brings colder water than usual into the Baltic. Superimposed on this comes also the influence of the ice-melting itself. The ice is formed in the Kattegat and melts at the expense of the heat of the surrounding water when it is carried out with the Baltic current into the Skagerak. The water around the ice gets cooler and sinks to the level of the under-current which thus becomes colder. The hydrographical statistics show that after a severe ice-winter a cold wave propagates itself towards the south with the under-current, through the Kattegat channel, from Skagen to the Great Belt. About four months after the disappearance of the ice, its after-effect is shown in the bottom water in the Great Belt and at the light-ship of Schulz Grund by a negative temperature-anomaly of abt. $1^1/_4$ degrees centigrade. That this after-effect comes as late as four months after the close of the ice-season must depend upon the fact that a double transport has here to be considered, that is: in the first place, of the melting ice with the surface-current out into the Skagerak and then of the cooled-off sinking water with the under-current southward through the Kattegat channel, this last mentioned transport taking about 2 to 3 months.

It is remarkable that ice-winters in the Transition Area occur periodically and that the period coincides with the secular herring-fishing periods, so that the most severe winters causing ice formation in the sea occur during these herring-fishing periods. For the same reason, at the present time, Sweden has, as a rule, milder winters with ice-free water in the Skagerak and the Kattegat. The last herring-fishing period ended in 1896. From 1896 to 1918 only 2 hard winters have occurred, that is, in 1909 and in 1917, while during the herring-fishing period that lasted from 1875 to 1897 there were 10 ice-winters, viz: 1875, 1876, 1879, 1881, 1886, 1888, 1889, 1891, 1893, 1895. Some of those winters were so severe that sea traffic entirely stopped for 1 to 2 months. The change came in the winter 1896—1897

[1]) Väderöbod light-house, situated 15 miles off the coast.

[2]) J. Gehrke: On the after-effect of ice-winters upon the deep-sea temperatures of the Kattegat. Publications de Circonstance N:o 75 (1922).

and was caused as already mentioned by a strong inflow of Atlantic water, which cut off the immigration of herring with the boreal water from the Norwegian Sea and brought about warmer water and milder climatic conditions within the Transition Area.

During the preceding secular herring-fishing period which lasted from 1750 to 1810 two groups of excessively cold ice-winters occurred just during the culmination of the winter herring-fishery. Such hard winters were thus experienced during 13 years[1]) that is: 1780, 1781, 1782, 1784, 1785, 1786, and 1790, 1800, 1802, 1803, 1804, 1805, 1809.

If one goes back still further into time, that is, back to the secular herring-fishing periods in the 16th, 15th, and 14th centuries, severe winters in the years 1660—1680; 1556—1587; 1419—1474, during which the Baltic itself froze to a great extent, are mentioned in contemporary chronicles.

In general the picture obtained about those climatic changes is as follows:—

Each secular herring-fishing period in the Transition Area has been accompanied by disturbances in our winter climate, which, judging from the investigations made during the last period 1876—1897, depend upon the checking of the Atlantic current and upon the prevailing inflow of boreal water from the Norwegian Sea through the Norwegian Channel.

This shows how important it is for future prognostications of the fishery and the winter-climate to carry out hydrographical researches into the conditions prevailing in the Norwegian Channel at various seasons and particularly in autumn and winter[2]).

The chief duty of hydrography is to study the water circulation in the Ocean and to account for the forces and the sources of energy that drive the current-system of the sea. The opinion now prevailing is that that energy is produced by outside mechanical causes: winds, changes in the pressure of the air, in the atmosphere, and hydrostatic over-pressure in the sea itself, by level-differences produced on account of differential warming of the surface-layer and of the dilution of the surface-water through rain and outflowing river-water from the continents etc. All these factors act upon the oceanic circulation but in most cases this effect is occasional and momentary. An outside mechanical cause

[1]) reckoned from 1780.

[2]) O. Pettersson: Kosmiska orsaker till rörelserna i havets och atmosfärens mellanskikt. Svenska Hydrografisk Biologiska Kommissionens Skrifter, Häfte VII.

can only be effective so long as it is continuous. In the Transition Area there is such a continuous effective cause, namely: the hydrostatic over-pressure from the Baltic which receives yearly more water from the rivers than can be evaporated[1]). The surplus is discharged through the current that passes through the Kattegat ("Baltic current").

It was believed that this surplus of river-water should cause a much higher water-level in the Baltic and slipshod calculations have given the difference in the height of the water between the Finnish Bay and the centre of the Norwegian Sea to be up to 2—3 metres and so on. Accurate levellings show that this is incorrect. In the average the difference of level between Gjedser (Baltic) and the Kattegat is only abt. 10 cm. and between Bottenviken and Westfjorden on the Norwegian coast, may be, double as much, therefore the hydrostatic over-pressure from the Baltic cannot be the primus movens of the water exchange occurring between the Ocean and the Baltic. That exchange is produced by a hydrodynamic pressure brought about by water of greater density than that in the Baltic, flowing through the Belt and sinking into the deep basin of the Baltic, driving up and replacing the lighter bottom-water. The inner circulation of water-layers in the form of wedges, which I have described in several preceding works and given again in the diagram, Figure 5, is thus produced in the whole Baltic. The little "water-fall" on the surface of the ocean of 10 cm. on the average, has an unimportant effect compared with the bigger submarine water-fall of 25 to 30 metres, which the under-current in the Kattegat performs at the southern end of the Great Belt and between the Arcona basin and the depths of Gotland, and so on. The internal energies acting here can be estimated by means of V. Bjerknes' solenoid theory, and the following diagram, showing a hydrodynamic section along the whole of the Baltic, from the Great Belt to Bottenviken, gives us an idea of its effect, see pag. 319. The illustration shows how the internal field of energy of the Baltic is concentrated in the Great Belt and in the Belt-Sea where the number of C. G. S. Solenoids is the largest. That internal field of energy acts like a stretched spring accelarating the water. When there is a strong air-pressure over the Baltic and an easterly wind, the surface-water is driven against the mouth of the Baltic and the height of the water rises. This works on the Solenoid field so that the isotherms become more vertical, — "the spring is stretched". At the

[1]) contrary to the Mediterranean.

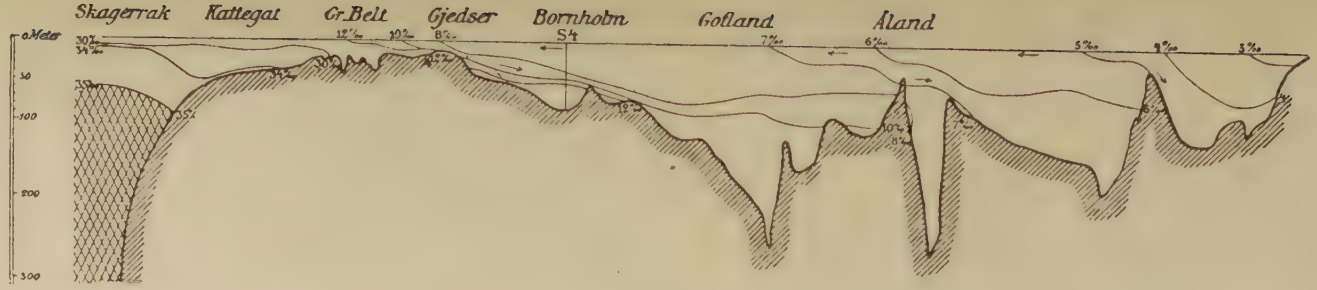


Fig. 5

Dynamic Sections of the Great Belt and the Baltic with C.G.S-Solenoids.

F. W. Sandström.

Fig. 6.

end of the driving up the isotherms become more horizontal, — "the spring becomes lax" and its potential energy is transformed into work, that is, by the acceleration of the out-going current until the stationary condition is restored.

The internal field of energy of the sea forms a conservative element in the water-circulation, which counteracts each occasional change and tends to bring back the condition of stationary balance which has etablished itself in the ocean in the course of thousands of years.

It was thought further, that the water-level of the Baltic would be governed by the rain-period and the ice-melting on the Continent. This hypothesis is, however, refuted by the diagram in Fig. 1, which shows that the highest and lowest water-mark occur (with a few weeks advance) simultaneously in the Baltic and on the coasts of Sweden and Holland, namely, in November and May. The maxima and minima of the water-level are not determined by the river-water from the Continent and by atmospheric conditions, but form the epochs of the yearly tidal wave of the ocean.

## Übersicht.

Der Wasserüberfluss der Ostsee entleert sich als Oberstrom durch das Kattegat, während ein Unterstrom von Meereswasser aus dem Norwegischen Meer und aus der Nordsee eindringt. Atlantisches Wasser von mehr als 35 $^{0}/_{00}$ Salzgehalt dringt wohl in das tiefe Skagerak-Bassin hinein, aber nicht weiter. Die erste Anzeige davon, dass dieser Einfluss von periodischer Natur ist, war die bekannte Beobachtung von Möbius und Heincke 1877 über die Erscheinung der s. g. "Südfische" in der letzten Hälfte des Jahres und der "Nordfische" in den ersten Monaten im Kattegat. Nach den späteren Untersuchungen von Gustaf Ekman, P. Cleve und O. Pettersson sind diese Fischwanderungen eng verknüpft mit einer hydrographischen Periodizität: nämlich einer jährlichen Tide des Ozeans, deren Flutzeit in den Herbst und deren Ebbezeit in den Frühling fällt. Pettersson, welcher diese Periodizität eingehend studiert hat, macht darauf aufmerksam, dass diese jährliche Tide sich kund gibt durch den jährlichen Wechsel des Wasserniveaus in der Nordsee und Ostsee, welches im November seinen höchsten und im Mai seinen niedrigsten Stand hat. Die Amplitude ist gering, 10—20 Zentimeter (Fig. 1). Auch die tägliche und halbtägliche Tidebewegung an der Oberfläche ist sehr klein in der Transition Area und ganz besonders auffallend ist es, dass diese grade vor der Südspitze Norwegens verschwindet, während 30 Meilen südlich davon an der jütischen Küste

der Tidenhub etwa 2 Meter beträgt. Der Verf. erklärt dies so, dass die Tidenwelle von der Nordsee vor dem Rande des Baltischen Stromes untertaucht und als interne Welle in der Zwischenschicht im Skagerak und Kattegat auftritt. Das Wellental wird ausgefüllt von dem leichteren baltischen Oberwasser, das sich wiederum über die Oberfläche ausbreitet, wenn der Wellenberg naht. Die vertikale Tide-Bewegung wird in eine horizontale verwandelt. Diese Dämpfung des Tidenhubs verschont die skandinavischen Länder mit den gewaltsamen Verheerungen von Sturmfluten. Die interne Tide in diesen Meeren zeigt sich in gewaltigen Wellenbewegungen an der Oberfläche des Unterstromes, welcher dadurch einen kaskadenhaften Verlauf erhält, worin langperiodische parallaktische Bewegungen auftreten, welche an der Oberfläche unmerklich sind, ihren Einfluss jedoch auf die Fischwanderungen ausüben.

Der quantitative Austausch von Wasser zwischen der Ostsee und dem Ozean ist eingehend studiert von den dänischen Hydrographen Knudsen, Jacobsen und Gehrke und theoretisch verifiziert durch R. Wittings Arbeiten. Über die sekulären Variationen in dem Wasseraustausch und in den Fischwanderungen in der Transition Area hat man Arbeiten von A. W. Ljungman und O. Pettersson. Der Übergang von der letzten grossen Heringsfischerei-Periode Skageraks im Winter 1896 wurde von Cleve, G. Ekman, J. Hjort und Pettersson studiert. Die grossen Heringsfischerei-Perioden von ungefähr 111 Jahren, über die seit dem 10. Jahrhundert historische Urkunden vorliegen, beruhen auf kosmischen Ursachen, nämlich auf dem Einfluss des Umlaufs der Knotenapside der Mondbahn auf die Flutkraft. Diese sekulären Perioden markieren zugleich den Wechsel unseres Winterklimas, welches durch Wechsel zwischen dem Einfluss des Atlantischen Wassers und dem borealen Wasser des Norwegischen Meeres im Skagerak im Herbst und Winter bestimmt wird. Der Wasseraustausch zwischen der Ostsee und dem Meere beruht nicht so sehr auf dem wechselndem hydrostatischen Überdruck von Seiten der Ostsee, sondern auf dem inneren Kraftfeld in den verschiedenen Wasserschichten, welches durch die Isostären und das Solenoiden-Netz nach Bjerknes' Theorie von J. W. Sandström ausgerechnet und durch das Diagramm Seite 319 repräsentiert ist.

# Currents and Fish-Migrations in the Transition Area

by

**Otto Pettersson.**

In the foregoing, I have alluded to the importance of the study of the under-current of the Kattegat on which depend the fish-life and the fisheries of the Baltic. This inflow of salt oceanic water is liable to great variations which stand in connection with the fish-migrations, e. g. the seasonal immigration of the herring in autumn and the mackerel in spring.

Beside these seasonal variations there are others of longer period which influence the extent of the areas over which the shoals of migratory fishes spread and the abundance or scarcity of the output of the fisheries. Dr. A. C. Johansen[1]) has studied a rare phenomenon of this kind, viz. the immigration of haddocks in the Belt Sea in 1923, which bears out the fact that migrations of other fishes than herrings and mackerel take place occasionally. This time the invasion had a decidedly passive character since it consisted not of full-grown fishes in search of food or spawning places but of larvae and fish-fry which, when they arrived in the Belts and the Belt Sea thrived and developed there in the following three years to such an extent that the catch of the Danish fishing-smacks which had been nil in 1922 and preceding years developed into an output of 59,000 Kg. in 1925 and to 500,000 Kg. in January and February this year. The fry from 1923 had then developed into haddocks of an average length of 37.4 centimeters, which is considerably greater than that which the same year-class attains in the Skagerak and the North Sea[2]).

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[1]) A. C. Johansen: On the Remarkable Quantities of Haddocks in the Belt Sea during the Winter of 1925—1926, and Causes leading to the same. Journal du Conseil International pour l'Exploration de la Mer, Vol. 1, No. 2, 1926.

[2]) According to the investigations of Harold Thompson: Problems in Haddock Biology I. Fisheries, Scotland. Sc. Investigation 1922 (May 1923).

The haddocks had evidently found favourable conditions with regard to food and growth in the Baltic though not for their reproduction. Seventy one individuals out of a catch of 80 haddocks in January 1926, were found ripe for spawning in the following months but the eggs were of a diminutive size, only 0.2 to 0.3 mm. The very promising haddock fishery in the Belt Sea declined already in the following month March this year, as could have been foreseen from two causes:—

1) In the years 1924 and 1925, after the great invasion of 1923, there had been only a scanty immigration — or shall we say inflow — of haddock-larvæ through the Kattegat. The development of the haddock fishery of the Belt Sea thus depended mainly on the product of a single year-class. Dr. JOHANSEN who has followed the development of this phenomenon by means of catches made on board the research-steamer Dana, with ring-trawls and young fish trawls has found ample evidence of this.

2) No spawning of haddocks has taken place in the Baltic although, as already mentioned, the full-sized haddocks of 37 cm. showed signs of ripening to maturity, nor have any haddock-larvae been found in the Belt Sea.

The very rapid decline of the haddock-fishery in this area after the great catches in January and February must be attributed either to the effect of intense fishing this winter, which has resulted in the depletion of this part of the sea of a stock of fishes unable there to reproduce their species, and which received no supply from without, or to an emigration of the grown up fishes for spawning purposes to such parts of the Sea where they could find more propitious conditions. The haddock ordinarily spawns in the northernmost part of the North Sea in water of 34.8 to 35 ‰ salinity and it seems natural that the fishes that were approaching maturity should try to find the way to the open sea. In such case, we can expect that their migration northwards will be marked by an increase in the catch of haddocks by the Swedish trawlers in the Kattegat this summer. Investigations are being carried out at present in Swedish sea-ports and market-places for this purpose.

The great haddock-fishery, during the winter 1925—26, was due to exceptional circumstances, viz. a strong inflow of salt water in spring 3 years before. To this inflow Dr. JOHANSEN ascribes also the abundant invasion of mackerel in the Skagerak and Kattegat in spring and summer 1923[1]).

[1]) A. C. JOHANSEN: On the influence on the currents upon the frequency of the Mackerel in the Kattegat and adjacent parts of the Skagerak. Meddelelser fra Kommissionen for Havundersøgelser. Ser. Fiskeri. Bd. VII, Nr. 8.

The mackerel has its habitat in winter on the deep northern plateau of the North Sea which is covered by Atlantic water of 35.00 to 35.25 ‰ salinity and 6°—7° temperature. When the mackerel leave their winter resort in April and May they gradually come up into water of between 34 ‰ and 35 ‰ salinity and it is known that this typical North Sea water circulates in such a manner that a portion of it streams into the Skagerak and further into the Kattegat where it forms the under-current (in spring) and gradually becomes mixed with Baltic water.

Now there was an unusually strong inflow of the under-current in spring 1923 which brought with it larvæ and fry of haddock in such quantity that it gave rise to a very remunerative fishery 2—3 years afterwards in the Belt Sea. In the same year 1923 the yield of the mackerel fishery in Skagerak and Kattegat attained 7760 tons, which counts among the maximum catches made this century.

Can we ascribe both these phenomena to the same cause, viz. the intense inflow from the ocean? That there is a connection between the variations of the under-current and the mackerel migrations is proved by the following coefficients of correlation, calculated by Mr. Aage Jensen, between the departures from the mean salinity of the under-current at the following light-ships in the spring-months, taken as index of the intensity of the under-current, and the corresponding departures from the ordinary catch of mackerel during the period 1909—1923:

| | | | | |
|---|---|---|---|---|
| Skagen Light-ship | (38 M.) | in March ..... | $r = 0.49$; | $\pm = 0.20$ |
| Anholt Knob — | (28 M.) | - April[1]) ..... | $r = 0.36$; | $\pm = 0.22$ |
| Schulz Grund — | (26 M.) | - May ..... | $r = 0.66$; | $\pm = 0.15$ |

From these premises Dr. Johansen has had the bold and brilliant idea of using the hydrographic data[2]) from light-ships as a base for prognostications regarding the coming fishing season in the Transition Area which he has as far as known hitherto made with success.

Dr. Johansen's research has a bearing on some much debated problems of the biology of fish in its relation to hydrography, e. g. the causes of fish-migrations. He has in the Transition Area found an experimental field of first order for the study of such matters.

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[1]) From the investigations of Professor M. Knudsen, Jacobsen, etc., we know that the flow of the under-current from Skagen to Schulz Grund takes, on the average, two months.

[2]) Dr. Johansen prefers to base such predictions on the temperature of the surface waters of the Kattegat in June, which is lower than usual when the salinity of the under-current has been high a month before.

Hydrographers consider that the migrations of fishes are governed by the oceanic circulation which is ruled by the law of continuity. Every current finds its compensation in another. The under-current of the Kattegat is an integral part of the circulation and has its counter-part in the outflowing, so-called, Baltic current. The fishes follow the water in which they live so long as it suits their physiological wants, i. e. until it becomes too cold or too diluted or void of oxygen or plankton, etc., in which case they seek refuge in the waters of the compensatory current or find a temporary rest in the intermediary layers where the motion is nil. It is a common experience of fishermen that the catches are richest in these layers. The fishes here in question alter their position in the vertical direction day and night, guided by the change of light and by the movement of the copepods, schizopods, etc., upon which they feed. In the Kattegat a rise of a few meters brings them into another medium in which they can remain if it suits their need or break their journey and follow with the current in the opposite direction.

In 1914 Dr. D. Nilsson, then assistant at the station of Bornö, studied the spawning of the mackerel in the Skagerak and Kattegat. He found that these fishes do not spawn in salter water than 32—33 $^0/_{00}$. The temperature limits he found to be 11° to 15°. Mackerel from the North Sea, arriving in spring with the under-current which brings water of more than 34 $^0/_{00}$ with a temperature of about 8°—10°, find in the boundary between the under-current and the upper layers of warmer and more diluted water propitious conditions for spawning and remain there during the summer. In July-August they become voracious and feed upon young fishes (herrings, whitings, etc.) in the fjords. In autumn, the mackerel leaves his haunts in the Skagerak and Kattegat and returns to the North Sea following the waters of the outgoing Baltic current[1])

The strength of the current of course exerts an influence upon the extension southwards of the migrations of fishes, e. g. of the herrings. In mediaeval time, from about 900 A. D. to the middle of the XVIth century, when the tidal force attained its maximal value, the migration of the herrings in autumn reached so far as to the entrance of the Baltic between Scania and Sealand. In later centuries the migration has usually been confined to the northern half of the Kattegat channel between Anholt and Læsö and in periods of slack tide, as at present, the greatest catches are made at the northern entrance to the Kattegat N. and E. of Skagen.

Such changes are due to long periodical variations of the tidal force

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[1]) Publications de Circonstance, No. 69, København 1914.

which rules the movement of the under-currents of the ocean[1]). Whenever the under-current of the Skagerak increases the circuit of the current-system widens and the migration of fishes extends to more southerly places in the Kattegat, the Belt Sea and even into the Baltic[2]) — abundant fishery; when the circuit narrows, the former fishing-places are abandoned — bad fishing-season.

The organisms which inhabit the ocean live under the influence of the osmotic pressure of the water which is caused by the molecules and ions of the dissolved salts. It is evident that this physical influence of the medium in which they live must cause a physiological reaction which increases in strength when the animals are ripe for spawning. The eggs will be deformed or burst if there is a notable inequality of osmotic pressure inside the cell membrane and the sea-water outside. The "instinct" which guides the fishes to their spawning grounds seems to be the physiological effect of the osmotic pressure of the surrounding water upon their reproductive organs which leads them there with infallible accuracy: the haddocks from the Belt Sea back to the North Sea, the mature eels from the innermost recesses of the Baltic to the Sargasso Sea. To discuss the spontaneity of such migration is idle. A closer study of the oceanic circulation and its periodicity, so long neglected and of which we know so little at present, will solve the mystery. We cannot reasonably doubt that the migration of the Leptocephalids of the eels to European waters, like the invasion of the larvae of the haddock into the Belt Sea, are of a passive nature: that the former are wafted with the waters of the Gulfstream from the Sargasso Sea to Ireland and the latter with the under-current of the Kattegat from the North Sea into the Baltic.

As for the return journey, the pathways of the Ocean, i. e. its current-system — hidden to us — is open to the fishes ready for spawning and which guided by the increase of salinity — as is the case with the haddocks and the eels in the Baltic — or by its decrease — as in the case of the mackerel in the North Sea — scent[3]) the opportunity to establish equilibrium between the inner and outer osmotic pressure and choose the right means of transport across the ocean, just as mariners use the tradewinds for the transit to America and the antitrades for the return journey.

[1]) O. Pettersson: Les mouvements internes dans la mer et dans l'air. Svenska Hydrografisk Biologiska Kommissionens Skrifter VII.

[2]) In the XIIth and XIIIth centuries the great herring fishery, the so-called Hanseatic herring fishery, extended so far.

[3]) An increase in the salinity of $1\,^0/_{00}$ corresponds to an increase of the osmotic pressure of about $^2/_3$ of an atmosphere.

# Uber die Verteilung von Temperatur und Salzgehalt des Wassers im Finnischen Meerbusen bei stationärem Stromzustande

von

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## I. Ableitung einer Beziehung zwischen Dichte und Strom bei stationärem Zustande.

Bei stationärem Stromzustande lässt sich die Dichteverteilung im Meere mittels V. Bjerknes' hydrodynamischer Formel[1])

$$\int_C^{\bullet} \frac{1}{\varrho} dp = -2\omega \frac{dS}{dt} - R \qquad (1)$$

berechnen. Die Integration wird längs der ganzen aus Wasserpartikeln zusammengesetzten Kurve $C$ ausgeführt. Hier bezeichnet $\varrho$ die Dichte des Wassers, $p$ den Druck, $\omega$ die Winkelgeschwindigkeit der Erde, $S$ die Projektion der von der Kurve $C$ umschlossenen Fläche auf der Äquatorebene und $R$ die Reibung. Im folgenden werden wir die Bewegung als reibungslos behandeln.

Wir werden die Dichtedifferenz zwischen zwei auf derselben isobaren Fläche gelegenen Punkten $A$ und $B$ mit dem gegenseitigen Abstand $\Delta l$ näher untersuchen. Annähernd können wir annehmen, dass die isobaren Flächen zugleich Horizontalflächen sind. Als geschlossene Kurve wird die aus zwei Vertikalen $\Delta z$ durch die Punkte $A$ und $B$ und zwei horizontalen Strecken $\Delta l$ zusammengesetzte gewählt, wobei zu beobachten ist, dass das Integral längs den isobaren (und annähernd horizontalen) Strecken $\Delta l$ keinen Beitrag erhält. Unter diesen Voraussetzungen kann das Integral

[1]) V. Bjerknes: Cirkulation relativ zu der Erde, Övers. af Kungl. Sv. Vetensk.-Akad. Förhandlingar, No. 10, 1901. J. W. Sandström und B. Helland-Hansen: Über die Berechnung von Meeresströmungen, Report on Norwegian Fishery- and Marine-Investigations, Vol. II, No. 4, 1902.

$$\int_{\cdot}^{C} \frac{1}{\varrho} dp = \left( \int_{z}^{z+\Delta z} \frac{1}{\varrho} dp \right)_{A} - \left( \int_{z}^{z+\Delta z} \frac{1}{\varrho} dp \right)_{B} \qquad (2)$$

geschrieben werden.

Um $\frac{dS}{dt}$ bei stationärem Strömungszustande berechnen zu können stellen wir folgende Annahme auf: In den Punkten $A$ und $B$ in der Tiefe $z$ ist die Stromgeschwindigkeit $v$, in der Tiefe $z + \Delta z$ $v + \Delta v$, während die Stromrichtung unverändert ist. Hieraus ergibt sich, dass

$$2\omega \frac{dS}{dt} = 2\omega \Delta v \Delta l \sin\varphi \sin\psi, \qquad (3)$$

wo $\psi$ den Winkel zwischen der Stromrichtung und der von der betrachteten Kurve eingeschlossenen Ebene bezeichnet und $\varphi$ die Polhöhe, die man hier für konstant halten kann, ist. Als positive Richtungen in einem rechtwinkligen Koordinatensystem wählen wir die Stromrichtung, die Richtung 90° nach links von der positiven Stromrichtung und die Richtung vertikal nach unten.

Bei der Integration betrachten wir das Meerwasser als eine inkompressible Flüssigkeit, deren Dichte eine Funktion von der Temperatur und dem Salzgehalt ist. Wenn die mittlere Dichte in den Vertikalen $A$ und $B$ $\varrho$ bzw. $\varrho + \Delta\varrho$ ist, erhalten wir nach (2) und (3)

$$\Delta p \left( \frac{1}{\varrho} - \frac{1}{\varrho + \Delta\varrho} \right) = -2\omega \Delta v \Delta l \sin\varphi \sin\psi, \qquad (4)$$

wo $\Delta p$ die Druckzunahme zwischen den Tiefen $z$ und $z + \Delta z$ angibt. Nun können wir annähernd

$$\Delta p = g\varrho \Delta z^{1})$$

setzen, wo $g$ die Schwerebeschleunigung bezeichnet. Durch Einführung dieses Wertes in (4) erhalten wir für $\Delta\varrho$ folgende Gleichung:

$$\Delta\varrho = -\frac{2\omega \sin\varphi}{g} \frac{\Delta v \Delta l}{\Delta z} (\varrho + \Delta\varrho) \sin\psi.$$

Wenn wir von kleinen Gliedern absehen, können wir $\varrho + \Delta\varrho = 1$ schreiben. Auf diese Weise erhält man folgende schliessliche Formel für die horizontale Dichtedifferenz:

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[1]) Hier ist angenommen, dass die isobaren Flächen äquidistante Horizontalflächen sind. Man könnte auch $\Delta p = g(\varrho + \Delta\varrho)\Delta z$ setzen.

$$\frac{\Delta \varrho}{\Delta l} = -\frac{2\omega \sin \varphi}{g} \frac{\Delta v}{\Delta z} \sin \psi. \tag{5}$$

Die Gleichung sagt uns folgendes: Der horizontale Dichtegradient steht senkrecht zur Stromrichtung. Die Dichtezunahme ist proportional der vertikalen Veränderung der Stromgeschwindigkeit. Das negative Vorzeichen bedeutet, dass, falls $A$ — wenn man in die Richtung des Stromes sieht — rechts von $B$ liegt, die Dichte in $A$ grösser ist, wenn die Stromstärke mit der Tiefe zunimmt, dagegen kleiner, wenn die Stromstärke abnimmt. Die Dichtedifferenz wird hierbei aus Gleichung (5) berechnet.

In dem gewählten Koordinatensystem hat man also annähernd

$$\frac{\partial \varrho}{\partial y} = -\frac{2\omega \sin \varphi}{g} \frac{\partial v}{\partial z}. \tag{5'}$$

Hieraus ergibt sich, wenn wir den Neigungswinkel $\beta$ der isopyknen Flächen, bestimmt durch die Gleichung

$$\frac{\partial \varrho}{\partial y} = \operatorname{tng} \beta \frac{\partial \varrho}{\partial z},$$

in (5') einführen, dass

$$\operatorname{tng} \beta = -\frac{2\omega \sin \varphi}{g} \frac{\frac{\partial v}{\partial z}}{\frac{\partial \varrho}{\partial z}}. \tag{6}$$

Diese Gleichung gibt, bei den im Ostseegebiete vorkommenden Stromgeschwindigkeiten annäherungsweise die Neigung der einzelnen $\varrho$-Flächen.

Wenn die Dichtezunahme $\frac{\partial \varrho}{\partial z}$ in einer verhältnismässig dünnen Wasserschicht sehr bedeutend ist, kann diese vorteilhaft als eine interne Diskontinuitätsfläche behandelt werden. Hierbei muss, damit stabiles Gleichgewicht bestehe, die Dichte des tieferen Wassers grösser sein. Wir betrachten hier näher eine Diskontinuitätsfläche, die aus der Berührungsfläche zwischen Oberflächen- und Tiefenwasser besteht. Bei dem Übergang vom Oberflächenwasser zum Tiefenwasser nimmt die Dichte sprungweise von $\varrho_1$ bis $\varrho_2$ zu. Wenn die Stromgeschwindigkeit $v_1$ bzw. $v_2$ ist, wird der Neigungswinkel der Diskontinuitätsfläche durch folgende Gleichung bestimmt[1]):

[1]) V. Bjerknes: On the dynamics of the circular vortex with applications to the atmosphere and atmospheric vortex and wave motions, Geof. Publ., Vol. II, No. 4 S. 16.

$$\operatorname{tng} \beta = -\frac{2\omega \sin \varphi}{g} \frac{\varrho_2 v_2 - \varrho_1 v_1}{\varrho_2 - \varrho_1}. \tag{7}$$

Wenn man in dieser Gleichung $\varrho_2 = \varrho_1 = 1.00$, $v_2 - v_1 = \Delta v$, $\varrho_2 - \varrho_1 = \Delta \varrho$ setzt, so geht sie in (6) über. Die für stetige Dichteverteilung abgeleiteten Formeln gelten also annähernd auch für interne Diskontinuitätsflächen. Inbetreff des Vorzeichens in Gleichung (7) gilt dieselbe Regel wie die früher für stetige Dichteverteilung angegebene.

Für die Neigung einer internen Diskontinuitätsfläche gilt also folgender Satz: Grenzen zwei Wasserschichten mit ungleicher Dichte an einander, so nimmt die Grenzfläche zwischen den Wassern eine Neigung an, die annähernd direkt proportional der Differenz der Stromgeschwindigkeit und umgekehrt proportional der Differenz der Dichte ist.

In Wirklichkeit hat man es nie mit reinen Diskontinuitäten zu tun, da bei der Berührung zweier Wasserschichten von verschiedener Dichte regelmässig eine gewisse Mischung beobachtet wird. An die Stelle einer sprungweisen Veränderung der Dichte an einer mathematisch definierten Fläche tritt eine verhältnismässig starke Veränderung der Dichte in einer Mischungsschicht endlicher Dicke. Nach (6) und (7) kann jedoch angenommen werden, dass die mittlere Neigung der $\varrho$-Flächen in der Mischungsschicht die Neigung einer internen Sprungschicht darstellt.

Unsere Formeln zeigen, dass Dichteverteilung und Stromzustand in dem Meere in Beziehung zu einander stehen ohne näher zu bestimmen, welche dieser Faktoren als der primäre zu betrachten ist. Entweder ist der Stromzustand von äusseren Faktoren wie Wind, Luftdruck, Wasserzufuhr und Gezeiten oder auch von dem Solenoidfelde des Meeres verursacht. Wir gehen nur auf die erstere Eventualität näher ein, welche in kleineren Binnenmeeren (wie die Ostsee) vorherrschend ist. Von den Gezeiten können wir ganz absehen, da unsere Formeln nur für stationäre Bewegungen gelten.

Die wichtigsten stromerzeugenden Faktoren sind: Wind, Luftdruckschwankungen und Wasserzufuhr. Die Wasserzufuhr geschieht in den Binnenmeeren teils durch Zufluss von Flusswasser (+ direkter Niederschlag — Verdunstung) von geringer Dichte, teils durch Zufluss salzreichen Wassers von grosser Dichte von den Weltmeeren. Hierbei entsteht ein nahe stationäres Stromsystem mit Abfluss von Oberflächenwasser und Zufluss von Tiefenwasser. Sieht man in die Richtung des Oberflächenstroms, hat man folglich in jeder Horizontalschicht rechts Wasser mit geringerem Salzgehalt und höherer Temperatur (wenn diese höher als die Temperatur des Dichte-

maximums ist). Aus der durchschnittlichen Neigung der $\varrho$-Flächen muss der normale Aus- und Einfluss berechnet werden können.

In der Regel wird dieser normale Stromzustand durch die Einwirkung des Windes bzw. des Luftdruckes gestört. Da die reine Windwirkung hierbei vorherrschend ist, beschränken wir uns ausschliesslich auf diese, besonders da der Effekt des Luftdruckes annähernd in derselben Richtung wirkt. Der durch den Winddruck verursachte Oberflächenstrom dringt schnell durch das ganze verhältnismässig homogene Oberflächenwasser bis zu einer gewissen Tiefe (Tiefe der Sprungschicht). Dieser Triftstrom nimmt nach V. W. Ekman [1]) mit der Tiefe an Stärke ab. Je stärker die Schichtung des Wassers ist, desto grösser wird auch die Geschwindigkeitsveränderung. Hierbei kann man regelmässig folgendes beobachten: In einem Gebiete wechselnder Tiefe ist das Wasser nahe an der Oberfläche fast homogen (Oberflächenwasser); danach folgt ein Gebiet mit ausgeprägter Schichtung (gemischtes Wasser) und schliesslich unterhalb desselben wiederum ein Gebiet mit schwacher Schichtung (Tiefenwasser). In der Mischungsschicht wird der Übergang vom Windstrom zum Tiefenstrom beobachtet.

Nach der Ekman'schen Stromtheorie verändert sich nicht nur die Stärke sondern auch die Richtung des Triftstromes mit der Tiefe. In Binnenmeeren von verhältnismässig geringer Tiefe kann doch die Stromrichtung annähernd als unverändert betrachtet werden. Dies gilt besonders dann, wenn das Meer eine solche Form hat, dass eine gewisse Richtung begünstigt wird. Hierbei wird angenommen, dass der Oberflächenstrom ohne Drehung in den Tiefenstrom (oft von genau entgegengesetzter Richtung) übergeht. Wir finden also folgende allgemeine Regel für die Beziehung zwischen Wind und Verteilung von Temperatur und Salzgehalt im Meere bei beschleunigungslosem, geradlinigem Strom:

Herrscht ein gewisser Wind lange genug, so verursacht er eine Veränderung in der horizontalen Temperatur- und Salzgehaltsverteilung des Wassers, die berechnet werden kann, wenn der vom Wind verursachte Triftstrom bekannt ist. Sieht man in die Richtung des Windes, so beobachtet man in jeder horizontalen Schicht nach rechts abnehmenden Salzgehalt und steigende Temperatur (wenn diese höher als die Temperatur des Dichtemaximums ist).

Diese vom Winde mittelbar hervorgerufene Dichteverteilung im Meere ist eine Folge der ablenkenden Kraft der Erdrotation. J. W. Sandström hat die direkte Einwirkung des Windes auf ein geschichtetes Wasser

[1]) V. W. Ekman: Om jordrotationens inverkan på vindströmmar i hafvet, Ak. avh., Uppsala 1902.

näher behandelt und dabei die Beziehung zwischen der Neigung der verschiedenen Schichten und dem Winddruck nachgewiesen[1]). In der Praxis ist es oft schwer zu entscheiden, ob eine im Meere beobachtete Schichtneigung direkt durch den Winddruck auf das Oberflächenwasser verursacht ist, oder ob sie eine Folge der Einwirkung der Erdrotation auf die durch den Wind hervorgerufenen Strömungen ist.

## II. Der hydrodynamische Zustand im Finnischen Meerbusen vom 1.—8. Juli 1925.

Die allgemeine synoptische Lage in der Zeit vom 1.—8. Juli 1925 war besonders geeignet für die Entwicklung eines nahe stationären Strömungszustandes im Finnischen Meerbusen. Während dieses Zeitabschnittes hatte man über dem ganzen Finnischen Meerbusen ausschliesslich östliche bis nordöstliche Winde. Obgleich die Windstärke mässig war, 1—6 Beauf. nach Angaben der Feuerschiffe und der festen meteorologischen Stationen an den Küsten, verursachte doch der anhaltende Wind in der Längenrichtung des Finnischen Meerbusens eine beträchtliche Strömung im Oberflächenwasser. Der resultierende Strom (aus sämtlichen Beobachtungen bestimmt) bei den Feuerschiffen Äransgrund (59°57′ N, 24°57′ E) und Revalstein[2]) (59°43′ N, 24°44′ E) für die Zeit 1.—8. Juli geht aus folgender Tabelle hervor.

Tab. 1. Resultierender Strom bei Äransgrund und Revalstein.

| Äransgrund | | Revalstein | |
|---|---|---|---|
| Tiefe, m. | Strom, cm/sek. | Tiefe, m. | Strom, cm/sek. |
| 0 | N 73° E 9.6 | 0 | S 82° E 17.7 |
| 15 | N 72° E 9.2 | 10 | S 79° E 14.6 |
| 30 | N 73° E 8.7 | 20 | S 82° E 10.2 |

Bei Äransgrund wurde also nur schwaches Abnehmen der Stromgeschwindigkeit in vertikaler Richtung beobachtet, während dagegen die Geschwindigkeitsänderung bei Revalstein beträchtlich war. Hierzu ist

[1]) J. W. Sandström: Deux théorèmes fondamentaux de la dynamique de la mer, Svenska Hydrog. Biol. Komm. Skrifter VII, 1922.

[2]) Die Beobachtungen von einigen estländischen Stationen sind mir gütigst von Dr. K. Frisch, Dorpat, mitgeteilt worden, wofür ich hiermit meinen verbindlichsten Dank aussprechen möchte.

noch zu bemerken, dass die Strommessungen in grösseren Tiefen in gewissem Grade von der Oberflächenströmung beeinflusst sind, und dass somit das Abnehmen der Stromgeschwindigkeit nach der Tiefe zu bei Revalstein tatsächlich noch etwas grösser sein muss als in Tab. 1. Die resultierende Stromrichtung, die nach der Tabelle von der Tiefe unabhängig ist, fällt ungefähr in die Hauptrichtung des Finnischen Meerbusens. Die Oberflächenströmung kann also annähernd als geradlinig behandelt werden.

Strombeobachtungen in grösserer Tiefe als 20—30 m liegen leider nicht vor. Dagegen ist es möglich auf indirektem Wege wenigstens qualitative Schlüsse in Betreff der Tiefenströmung zu ziehen. Wenn man annimmt, dass die Stromgeschwindigkeit von der Oberfläche bis 20 m Tiefe durchschnittlich 10 cm pro sek. in einem Querschnitt von 50 km Länge ist, so wird durch diesen Querschnitt während der Zeit vom 1.—8. Juli in abgerundeter Zahl 70 km³ Wasser transportiert. Diese Wasserabgabe bedeutet eine Senkung der Wasserfläche des ganzen Finnischen Meerbusens von etwa 2 m. Da der jährliche Süsswasserzufluss in den Finnischen Meerbusen nach Witting[1]) sich auf ungefähr 114 km³ beläuft, kann er nicht wesentlich auf die Senkung der Wasserfläche einwirken. Man muss also annehmen, dass der Wasserverlust durch einen Gegenstrom in der Tiefe ersetzt wird.

Der Wasserstand in Helsingfors war für den betreffenden Zeitabschnitt, auf die finnländische Referenzfläche bezogen (ungefähr 200 cm unter dem Normalwasserstande), folgender in Tagesmitteln (cm):

Tab. 2. Wasserstand in Helsingfors 1.—8. Juli.

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|
| 202 | 197 | 197 | 198 | 195 | 194 | 197 | 197 |

Während des betreffenden Zeitabschnitts blieb der Wasserstand ziemlich unverändert trotz des kräftigen Wassertransports auswärts vom Finnischen Meerbusen. Dieser Umstand lässt sich nur durch die Annahme einer kräftigen einwärtsgehenden Strömung in der Tiefe erklären. Die Geschwindigkeit dieses Tiefenstroms, der den Charakter eines Reaktionsstroms hat, muss so gewählt werden, dass die Wassermenge des Finnischen Meerbusens annähernd konstant bleibt. Im folgenden

[1]) Siehe R. Witting: Hafsytan, geoidytan och landhöjningen utmed Baltiska hafvet och vid Nordsjön, Fennia 39, No. 5, S. 105.

Tab. 3. Temperatur, Salzgehalt und Dichte in verschiedenen Tiefen.

| Station | | | 0 m | | | 10 m. | | | 20 m. | | | 30 m. | | | 40 m. | | | 50 m. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | N | E | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ |
| 44 | 60°08′ | 26°58′ | 15.2 | 4.07 | 2.27 | 13.8 | 4.11 | 2.52 | 10.6 | 4.34 | 3.10 | 3.8 | 5.63 | 4.53 | 2.9 | 6.33 | 5.11 | 3.3 | 7,11 | 5.72 |
| 51A | 60°07′ | 24°59′ | 17.0 | 4.13 | 2.00 | 16.3 | 4.18 | 2.17 | 15.2 | 4.36 | 2.50 | 13.8 | 4.58 | 2.88[1]) | — | — | — | — | — | — |
| 52A | 60°01′ | 24°58′ | 16.4 | 4.07 | 2.07 | 15.3 | 4.13 | 2.29 | 13.6 | 4.43 | 2.80 | 6.5 | 5.07 | 3.99 | 4.4 | 6.22 | 4.99 | — | — | — |
| 53 | 59°52′ | 24°50′ | 14.5 | 4.31 | 2.56 | 14.0 | 4.27 | 2.61 | 11.7 | 4.60 | 3.17 | 6.4 | 5.99 | 4.72 | — | — | — | 3.3 | 6.74 | 5.43 |
| 58 | 59°47′ | 23°00′ | 15.6 | 4.70 | 2.69 | 15.5 | 4.70 | 2.71 | 15.2 | 4.72 | 2.77 | 13.9 | 4.85 | 3.07 | 11.7 | 5.77 | 4.08[2]) | — | — | — |
| 59A | 59°39′ | 23°05′ | 14.8 | 5.08 | 3.11 | 14.1 | 5.01 | 3.17 | 13.0 | 5.32 | 3.56 | 9.4 | 5.84 | 4.38 | 4.0 | 6.74 | 5.42 | 3.4 | 7.30 | 5.88 |
| 45 | 59°57′ | 27°00′ | 14.6 | 4.06 | 2.34 | 13.8 | 4.11 | 2.51 | 8.3 | 4.40 | 3.35 | 3.0 | 6.00 | 4.84 | 2.9 | 6.56 | 5.29 | 3.0 | 6.89 | 5.55 |
| 49 | 59°52′ | 26°17′ | 13.6 | 4.00 | 2.46 | 12.6 | 4.15 | 2.71 | 3.5 | 6.02 | 4.86 | 2.9 | 6.55 | 5.27 | 3.0 | 6.89 | 5.55 | 3.3 | 7.29 | 5.87 |
| 50 | 59°50′ | 25°37′ | 14.3 | 4.24 | 2.53 | 12.7 | 4.24 | 2.76 | 4.3 | 5.70 | 4.59 | 3.2 | 6.46 | 5.20 | 3.2 | 6.62 | 5.33 | 3.1 | 7.12 | 5.74 |
| 54 | 59°43′ | 25°01′ | 14.9 | 4.70 | 2.81 | 11.2 | 4.92 | 3.49 | 6.0 | 6.17 | 4.89 | 4.0 | 6.78 | 5.45 | 3.4 | 6.96 | 5.60 | 3.5 | 7.36 | 5.92 |
| 57 | 59°30′ | 23°44′ | 15.6 | 5.39 | 3.22 | 13.2 | 5.50 | 3.66 | 6.5 | 6.42 | 5.06 | 4.4 | 6.71 | 5.38 | 4.4 | 6.76 | 5.43 | — | — | — |
| 61 | 59°26′ | 23°09′ | 15.7 | 5.61 | 3.35 | 12.6 | 5.41 | 3.69 | 8.2 | 6.09 | 4.69 | 5.4 | 6.80 | 5.42 | 3.9 | 6.82 | 5.48 | 3.2 | 7.09 | 5.71 |
| 72 | 59°15′ | 22°11′ | 16.1 | 5.97 | 3.57 | 9.6 | 6.26 | 4.69 | 5.1 | 6.76 | 5.40 | 3.8 | 6.91 | 5.54 | 3.4 | 7.02 | 5.64 | 3.3 | 7.14 | 5.75 |
| 73 | 59°01′ | 21°52′ | 16.1 | 5.95 | 3.56 | 11.0 | 6.65 | 4.85 | 5.9 | 6.76 | 5.37 | 4.2 | 6.94 | 5.57 | 3.3 | 7.32 | 5.89 | 3.3 | 7.43 | 5.98 |
| 55 | 59°38′ | 25°11′ | 9.4 | 5.86 | 4.40 | 4.6 | 6.00 | 4.81 | 4.6 | 6.46 | 5.17 | 3.9 | 6.69 | 5.38 | 3.6 | 6.78 | 5.45 | — | — | — |
| — | 59°40′ | 24°43′ | 10.5 | 6.29 | 4.63 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 56 | 59°37′ | 24°21′ | 12.8 | 5.82 | 3.98 | 7.0 | 6.42 | 5.03 | 4.5 | 6.70 | 5.38 | 3.5 | 6.87 | 5.52 | 3.2 | 7.11 | 5.72 | — | — | — |
| — | 59°18′ | 23°22′ | 7.5 | 6.70 | 5.22 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | 59°20′ | 23°21′ | 8.5 | 6.55 | 5.02 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 62 | 59°20′ | 23°16′ | 11.2 | 6.42 | 4.64 | 6.3 | 6.69 | 5.29 | 3.7 | 6.89 | 5.54 | 3.3 | 7.05 | 5.68 | 3.1 | 7.21 | 5.81 | 3.5 | 8.15 | 6.53[3]) |

[1]) 24 m. [2]) 35 m. [3]) 55 m.

kommen wir noch auf die Schätzung der Geschwindigkeit des Tiefenstroms zurück, nachdem wir erst die Grösse der beiden Stromgebiete geschätzt haben.

Wir gehen nun zur Temperatur- und Salzgehaltsverteilung über. Da die vom Institut für Meeresforschung vorgenommene Terminfahrt in

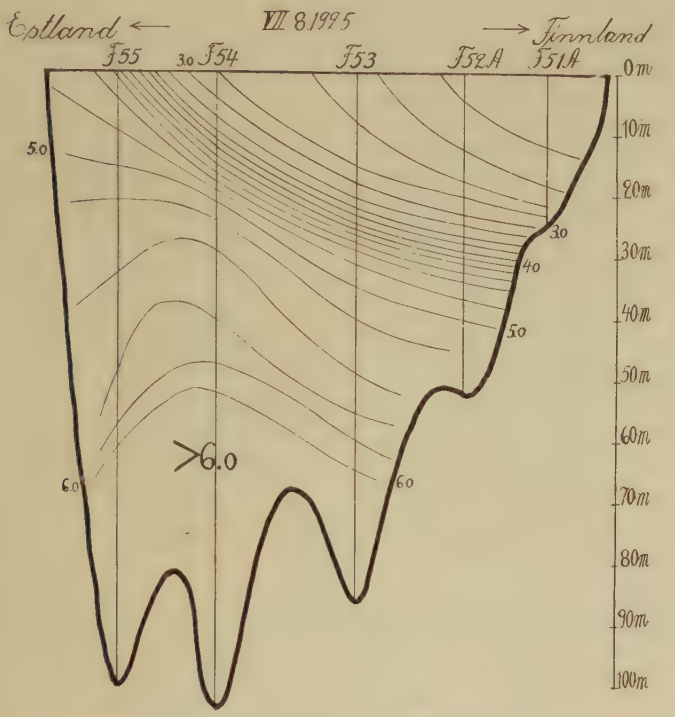


Diagramm 1. Die $\sigma_t$-Kurven im Querschnitt I.

dieselbe Zeit fiel, steht uns ein reichhaltiges Beobachtungsmaterial zur Verfügung. In der nebenstehenden Tabelle ist ein Teil der Beobachtungen zusammengestellt. Die Tabelle umfasst drei Abteilungen, nämlich: Beobachtungen in der Nähe der finnländischen Küste, in der Mitte des Finnischen Meerbusens und in der Nähe der estländischen Küste[1]).

Die Werte $\sigma_t$ geben die Dichte $\varrho$ des Wassers bei der Temperatur $t°$ und dem Salzgehalt $S\,‰$ nach der Gleichung $\sigma_t = (\varrho - 1)\,1000$. Die Dichte ist nach Knudsens hydrographischen Tabellen aus Temperatur und Chlorgehalt des Wassers berechnet.

[1]) Die vollständigen Beobachtungen sind publiziert in: Die thalassologische Terminfahrt im Jahre 1925, Havsforskningsinstitutets Skrift No. 39, Helsingfors 1926.

Wenn wir die Mächtigkeit der Oberflächenschicht an den verschiedenen Stationen in Tab. 3 betrachten, so beobachten wir eine allmählich abnehmende Mächtigkeit je näher der estländischen Küste die Station liegt. Die $\sigma_t$-Flächen zeigen somit eine starke Neigung in den Schnitten senkrecht gegen die Längenrichtung des Finnischen Meerbusens. Ferner beobachten wir an jeder Station ein Gebiet

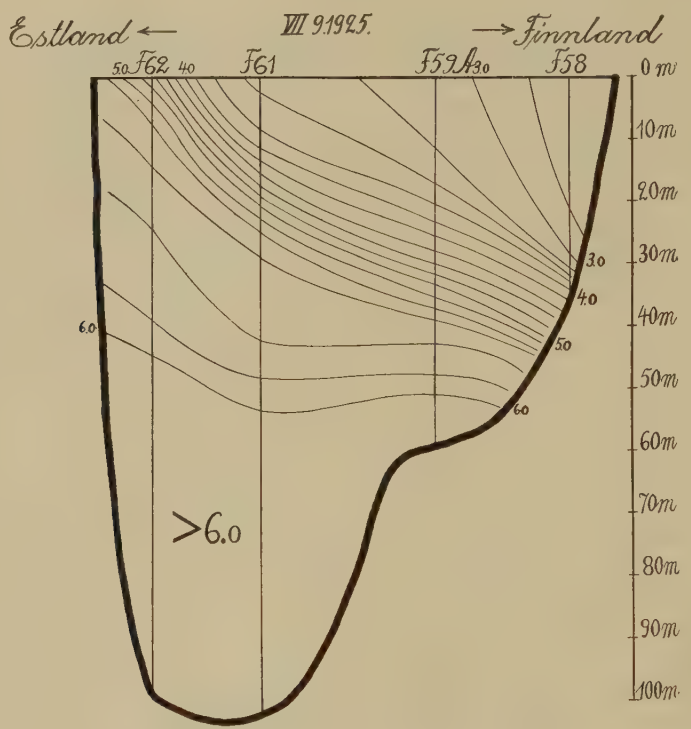


Diagramm 2. Die $\sigma_t$-Kurven im Querschnitt II.

starker Dichtigkeitszunahme mit der Tiefe. Dieses Gebiet repräsentiert die Sprungschicht (oder Mischungsschicht) zwischen Oberflächen- und Tiefenwasser. Die durchschnittliche Neigung dieser Sprungschicht werden wir im folgenden berechnen.

Die Berechnungsmethode ist folgende: Wir wählen zwei Querschnitte annähernd senkrecht gegen die mittlere Richtung des Finnischen Meerbusens und einen Längenschnitt ungefähr die Mittellinie des Finnischen Meerbusens entlang. Querschnitt I (Linie F 52A—F 55) läuft von Helsingfors bis südlich von Kokskär, Querschnitt II (Linie F 58—F 62) von Hangö bis Odinsholm. In Schnitt I können 5, in Schnitt II 4 der in Tab. 3 angegebenen Tiefenstationen approximativ untergebracht

werden. Alle diese Beobachtungen können als gleichzeitig betrachtet werden. (Die Messungen sind nämlich während der Zeit 8. Juli um 13 Uhr—9. Juli um 10 Uhr ausgeführt). Die Diagramme 1 und 2 geben den Verlauf der $\sigma_t$-Kurven innerhalb dieser Querschnitte an. Wenn der Tiefenunterschied einer gewissen $\sigma_t$-Kurve an den Endpunkten eines Schnittes bekannt ist, erhält man die mittlere Neigung der Kurve durch Division der Tiefendifferenz mit dem horizontalen Abstand der Punkte. Die Neigung der einzelnen $\sigma_t$-Kurven der Sprungschicht in den Schnitten I und II geht aus folgenden Tabellen hervor:

Tab. 4. Die Neigung der $\sigma_t$-Kurven im Schnitt I (Länge 45 km).

| $\sigma_t$ | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $10^4 \times \mathrm{tng}\,\beta$ | 6.7 | 6.8 | 6.9 | 7.0 | 7.1 | 7.2 | 7.2 | 7.2 | 6.9 | 6.1 | 5.6 |

Tab. 5. Die Neigung der $\sigma_t$-Kurven im Schnitt II (Länge 36 km).

| $\sigma_t$ | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 | 5.2 | 5.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $10^4 \times \mathrm{tng}\,\beta$ | 7.2 | 7.4 | 7.7 | 8.1 | 8.5 | 8.7 | 8.9 | 8.9 | 8.8 | 8.3 | 7.0 |

Im Längenschnitt senkrecht gegen diese Querschnitte wird dagegen keine ausgeprägte Neigung der einzelnen $\sigma_t$-Linien beobachtet, wie aus nachstehender Tabelle hervorgeht.

Tab. 6. Die Neigung der $\sigma_t$-Kurven im Längenschnitt (Länge 112 km).

| $\sigma_t$ | 3.4 | 3.6 | 3.8 | 4.0 | 4.2 | 4.4 | 4.6 | 4.8 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|
| $10^4 \times \mathrm{tng}\,\beta$..... | 0.7 | 0.4 | 0.2 | 0.0 | — 0.1 | — 0.2 | — 0.2 | — 0.2 | — 0.2 |

Die maximale Neigung der Sprungschicht fällt somit annähernd in die Richtung senkrecht gegen die resultierende Stromrichtung. Die Grösse der Neigung schwankt etwas für die einzelnen $\sigma_t$-Flächen und beläuft sich im Schnitt I durchschnittlich auf $6.8 \times 10^{-4}$, im Schnitt II auf $8.1 \times 10^{-4}$.

Wenn die Neigung der Sprungschicht bekannt ist, so können wir die

vertikale Stromveränderung nach (6) oder (7) schätzen. Für $\varphi = 60°$, $g = 982$ cm/sek$^2$ und $\omega = 7.29 \times 10^{-5}$ sek$^{-1}$ erhalten wir

$$\Delta v = 7.8 \times 10^6 \Delta \varrho \operatorname{tng} \beta \qquad (8)$$

Für eine mittlere Neigung $7.5 \times 10^{-4}$ erhalten wir folgende Wertpaare

Tab. 7. Entsprechende Werte für $\Delta \sigma_t$ und $\Delta v$.

| $\Delta \sigma_t$ ..... | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 |
|---|---|---|---|---|---|---|
| $\Delta v$ ..... | — 11.7 | — 12.9 | — 14.0 | — 15.2 | — 16.4 | — 17.5 |

Rechnet man mit einer Stromgeschwindigkeit von 10—12 cm pro sek. in der Oberflächenschicht, welche Geschwindigkeit als Mittel der Beobachtungen an den Feuerschiffen Kalbådagrund, Äransgrund, Revalstein[1]) und Nekmansgrund hervorgeht, muss der auswärtsgehende Oberflächenstrom nach Tab. 7 in einen einwärtsgehenden Tiefenstrom in der Tiefe der $\sigma_t$-Flächen 5.0—5.4 übergehen. Die $\sigma_t$-Flächen 5.0—5.4 bezeichnen die untere Begrenzung der Sprungschicht; geht man noch tiefer, so nimmt der einwärtsgehende Strom an Stärke zu.

Wenn man die Tiefenverhältnisse und die Mächtigkeit des Oberflächenwassers in den beiden Querschnitten kennt, so kann man die durchschnittliche Geschwindigkeit dieser einwärtsgehenden Tiefenströmung schätzen. Damit die ganze Wassermenge des Finnischen Meerbusens während der Zeit 1.—8. Juli annähernd konstant sein soll (in Übereinstimmung mit den Wasserstandbeobachtungen Tab. 2), findet man, dass die mittlere Geschwindigkeit des Tiefenstroms auf ungefähr $^2/_3$ der Geschwindigkeit des Oberflächenstroms geschätzt werden muss. Die berechnete Veränderung der Stromgeschwindigkeit mit der Tiefe stimmt also gut mit der beobachteten Schichtneigung überein.

Wir betrachten besonders die Strombeobachtungen bei Revalstein. Die Dichte an der Meeresoberfläche ist hier annähernd 1.0029, in 10 m Tiefe 1.0035 und in 20 m Tiefe 1.0049, wie man durch Vergleich mit der nahegelegenen Station F 54 N von Kokskär findet. Hieraus berechnen wir nach (8) folgende Werte für die Veränderung $\Delta v$ der Stromgeschwindigkeit mit der Tiefe[2]). Die beobachteten Werte $\Delta v_{\text{beob.}}$ sind aus Tab. 1 genommen.

---

[1]) An Revalstein ist die Stromgeschwindigkeit grösser als an den anderen Feuerschiffen, was wahrscheinlich auf der Enge des Finnischen Meerbusens gerade in diesem Querschnitte beruht.

[2]) Bei der Berechnung ist die für Schnitt I geltende Neigung $6.8 \times 10^{-4}$ angewandt worden.

Tab. 8. Berechnete und beobachtete Stromveränderung bei Revalstein.

| Tiefe | $\Delta\sigma_t$ | $\Delta v_{ber.}$ | $\Delta v_{beob.}$ |
|---|---|---|---|
| 0—10 m | +0.6 | —3.2 cm/sek | —3.1 cm/sek |
| 10—20 » | +1.4 | —7.4 » | —4.4 » |
| 0—20 » | +2.0 | —10.6 » | —7.5 » |

Hier ist noch zu bemerken, dass die beobachtete Stromveränderung auf Grund der Mängel in der Messungsmethode regelmässig etwas kleiner als die wirkliche ist. Mit Hinsicht hierauf ist die Übereinstimmung zwischen Theorie und Beobachtung in der Wirklichkeit sicherlich besser als in Tab. 8.

Besonders beleuchtend für den hydrodynamischen Zustand während der Zeit 1.—8. Juli sind die Beobachtungen bei Nekmansgrund (59°6′ N 22°12′ E). Hier wurde am 1.—2. und 7.—8. Juli Strom von N bis E, am 3.—6. Juli dagegen von S bis W beobachtet. Werden die dreimal täglich gemachten Strom- bzw. Temperaturbeobachtungen zusammengestellt, so erhalten wir folgende Kombinationen von Strom und Oberflächentemperatur. Beobachtungen von Tiefentemperatur und Salzgehalt stehen mir leider nicht zur Verfügung.

Tab. 9. Strom und Oberflächentemperatur bei Nekmansgrund.

| Resultierender Strom cm/sek | | | Oberfl. Temperatur |
|---|---|---|---|
| 0 m | 10 m | 20 m | |
| N 69° E 10.2 | N 80° E 7.0 | N 87° E 5.6 | 12.4° |
| S 18° W 1.5 | S 34° W 4.0 | S 31° W 4.2 | 8.7° |

Aus der Tabelle geht hervor, dass die Stärke des auswärtsgehenden Stromes nach der Tiefe zu abnahm, während die Stärke des einwärtsgehenden Stromes zunahm. Die Temperatur des Oberflächenwassers war niedrig im Vergleich mit der Wassertemperatur der Ostsee (am 8. Juli 13—16° an der Oberfläche), aber ungefähr 4° niedriger bei einwärtsgehendem als bei auswärtsgehendem Strome. Hieraus können wir schliessen, dass Nekmansgrund sich während der Zeit 1.—2. und 7.—8. Juli im Gebiete des Oberflächenstromes und vom 3.—6. Juli im Gebiete des Tiefenstromes befand. Infolge störender Faktoren, wie starke Insolation,

Mischungsphenomene u. s. w., konnte die Temperatursenkung bei einwärtsgehendem Strome nicht völlig zu ihrem Rechte kommen. Dass die Temperatur bei SW-Strom tatsächlich etwa 5—6° niedriger als die Oberflächentemperatur der Ostsee war, beweist jedenfalls, dass das Wasser an der Oberfläche bei Nekmansgrund wenigstens stark mit Tiefenwasser vermischt war. Da Nekmansgrund ausserhalb des Finnischen Meerbusens liegt, können wir die früher bestimmte Schichtneigung doch nicht direkt mit der Veränderung der Stromgeschwindigkeit vergleichen.

Wir fassen noch einmal die wichtigsten Ergebnisse in folgende allgemeine Punkte zusammen:

1) Unter der Einwirkung andauernder östlicher Winde entwickelte sich im Finnischen Meerbusen in der Zeit vom 1.—8. Juli ein nahe stationärer Strömungszustand mit auswärtsgehendem Strom im Oberflächenwasser und einwärtsgehendem Strom im Tiefenwasser.

2) Durch Einwirkung der Erdrotation auf diesen Stromzustand erhielten die isopyknen Flächen eine Neigung, die ihren geringsten Wert in der Richtung des Oberflächenstroms (annähernd horizontaler Verlauf) und ihren grössten Wert in der Richtung senkrecht gegen den Oberflächenstrom hat.

3) Aus dem beobachteten Oberflächenstrom und dem geschätzten Tiefenstrom wurde die Neigung der Sprungschicht nach den Formeln (6) oder (7) berechnet; diese berechnete Neigung stimmt gut mit der wirklich beobachteten überein.

## III. Verteilung von Temperatur und Salzgehalt im Finnischen Meerbusen bei verschiedenem Strömungszustande.

Durch folgende Regel ist die horizontale Temperatur- und Salzgehaltverteilung im Finnischen Meerbusen bestimmt: Bei anhaltendem Oberflächenstrom von W nimmt die Dichte des Wassers an den Küsten Finnlands zu, bei anhaltendem Oberflächenstrom von E nimmt die Dichte ab. Umgekehrt ist das Verhältnis an den Küsten Estlands. Da der Oberflächenstrom vom Winde abhängt, so gilt dieselbe Regel für die Beziehung zwischen Wind und Verteilung von Temperatur und Salzgehalt. Aus dem normalen Wassertransport auswärts in den Oberflächenschichten und einwärts in den tieferen Schichten lässt sich die mittlere Dichtigkeitsdifferenz zwischen den Küsten Finnlands und Estlands berechnen, welche bei der normalen Wassertemperatur (nahe + 5° C) hauptsächlich vom Salzgehalt abhängig ist.

Da wir den normalen Unterschied im Salzgehalt zwischen Helsingfors (Gråhara) und Kokskär kennen, können wir die entsprechende Veränderung der Stromgeschwindigkeit mit der Tiefe nach (5) berechnen. Nach WITTING[1]) ist der mittlere Oberflächensalzgehalt ausserhalb Helsingfors etwa 4.90 ‰, in der Gegend von Kokskär etwa 5.25 ‰. Der Unterschied beläuft sich also auf ungefähr 0.35 ‰ in einer Entfernung von rund 55 km. Wenn die Dichte als eine Funktion von nur Salzgehalt betrachtet wird, so erhält man für eine Mitteltemperatur von + 5° C den Dichteunterschied $\Delta\varrho = 0.00027$. Gleichung (5) ergibt eine entsprechende Veränderung der Stromgeschwindigkeit von — 0.4 cm/sek. pro 10 m in vertikaler Richtung. Den resultierenden auswärtsgehenden Strom am Feuerschiff Äransgrund habe ich aus sämtlichen Strombeobachtungen für die Jahre 1910—1914 und 1919—1923 auf etwa 1 bis 1.5 cm/sek. geschätzt. Die berechnete durchschnittliche Geschwindigkeitsveränderung — 0.4 cm/sek. pro 10 m steht also in gutem Einklang mit den Strombeobachtungen bei Äransgrund.

Um das oben gesagte zu verdeutlichen, führe ich noch folgende Werte für den Unterschied im Salzgehalt zwischen Gråhara (60°6′ N 24°59′ E) und Äransgrund (59°57′ N 24°57′ E) bei verschiedenem Strom an. Die Mittelwerte gelten für die Zeit VI 1.—X 11. 1913[2]), welche Zeit sich durch ungewöhnlich stabilen Strömungszustand auszeichnete.

Tab. 10. Salzgehalt des Wassers bei Gråhara und Äransgrund VI. 1.—X. 11. 1913.

| Tiefe | E-Strom | | | Wechselnder Strom | | | W-Strom | | |
|---|---|---|---|---|---|---|---|---|---|
| | G | Ä | G—Ä | G | Ä | G—Ä | G | Ä | G—Ä |
| | ‰ | ‰ | ‰ | ‰ | ‰ | ‰ | ‰ | ‰ | ‰ |
| 0 m .... | 4.79 | 4.91 | — 0.12 | 5.16 | 5.09 | + 0.07 | 5.20 | 5.09 | + 0.11 |
| 10 » .... | 4.93 | 5.15 | — 0.22 | 5.30 | 5.31 | — 0.01 | 5.57 | 5.23 | + 0.34 |
| 20 » .... | 5.11 | 5.64 | — 0.53 | 5.82 | 5.88 | — 0.06 | 6.16 | 5.94 | + 0.22 |
| 30 » .... | 5.78 | 6.28 | — 0.50 | 6.25 | 6.30 | — 0.05 | 6.83 | 6.54 | + 0.29 |

Bei östlichem Strom beobachtet man in jeder Tiefe höheren Salzgehalt bei Äransgrund als bei Gråhara, bei westlichem Strom ist das Verhältnis entgegengesetzt, während bei wechselnder Stromrichtung kein auffallender Unterschied zwischen Gråhara und Äransgrund besteht. Salzgehaltbeobachtungen in verschiedenen Tiefen bei Gråhara und Äräns-

[1]) ROLF WITTING: Finnl. Hydr.-Biol. Unters. No. 7.

[2]) Nach ROLF WITTING: Finnl. Hydr.-Biol. Unters. No. 13.

grund geben somit gute Übereinstimmung mit der Theorie.

Bei starkem Winde von S bis W oder NW wird das Oberflächenwasser in der Regel mit grosser Geschwindigkeit in den Finnischen Meerbusen getrieben. Hierbei kann ein dem normalen entgegengesetzter Strömungszustand mit auswärtsgehendem Tiefenstrome entstehen. Nebenstehende Tabelle gibt die Verteilung von Temperatur, Salzgehalt und Dichte in dem Querschnitte I (Helsingfors—Kokskär) bei anhaltenden frischen Winden von S bis SW. Die Beobachtungen sind vom 2. Oktober 1900[1]).

Die Schichtneigung ist, wie aus der Tabelle hervorgeht, der früher besprochenen (am 8. Juli 1925) entgegengesetzt. Der vom Winde verursachte Strom presst unter Einwirkung der ablenkenden Kraft der Erdrotation das leichtere Oberflächenwasser gegen die estländische Küste, das schwerere Tiefenwasser wiederum gegen die finnländische Küste. Die Neigung der Dichtigkeitsflächen stimmt also qualitativ mit unserer Regel für die Beziehung zwischen Dichte und Strom im Meere überein. Die quantitative Übereinstimmung nach Gleichung (6) kann dagegen infolge mangelnder Strombeobachtungen nicht geprüft werden.

Tab. 11. Temperatur, Salzgehalt und Dichte des Wassers im Querschnitt I bei S- bis SW-Wind am 2. X. 1900.

| Station | | 0 m. | | | 10 m. | | | 20 m. | | | 30 m. | | | 40 m. | | | 50 m. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | E | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ | $t°$ | $S‰$ | $\sigma_t$ |
| 60°01′ | 24°46′ ..... | 6.8 | 6.40 | 5.04 | 6.7 | 6.42 | 5.05 | 5.0 | 6.48 | 5.18 | 4.1 | 6.59 | 5.30 | 3.6 | 6.70 | 5.39 | — | — | — |
| 59°55′ | 24°48′ ..... | 8.1 | 6.33 | 4.89 | 8.1 | 6.33 | 4.89 | 7.9 | 6.33 | 4.90 | 5.4 | 6.52 | 5.19 | 2.5 | 6.87 | 5.53 | 2.3 | 6.94 | 5.59 |
| 59°52′ | 24°53′ ..... | 10.2 | 6.22 | 4.60 | 10.2 | 6.24 | 4.61 | 9.9 | 6.28 | 4.67 | 3.9 | 6.54 | 5.25 | 2.0 | 6.96 | 5.61 | 1.9 | 7.06 | 5.69 |
| 59°47′ | 24°49′ ..... | 10.8 | 6.13 | 4.47 | 10.6 | 6.13 | 4.49 | 10.3 | 6.22 | 4.59 | 8.9 | 6.33 | 4.82 | 2.5 | 6.61 | 5.32 | 1.7 | 7.03 | 5.67 |
| 59°44′ | 24°58′ ..... | 11.3 | 6.02 | 4.32 | 11.3 | 6.02 | 4.32 | 11.3 | 6.02 | 4.32 | 11.3 | 6.04 | 4.33 | 10.5 | 6.08 | 4.46 | 1.8 | 6.88 | 5.54 |
| 59°39′ | 25°02′ ..... | 11.4 | 5.52 | 3.92 | 11.4 | 5.56 | 3.95 | 11.4 | 5.54 | 3.93 | 11.4 | 5.54 | 3.93 | 8.4 | 5.93 | 4.56 | 2.3 | 6.99 | 5.63 |

[1]) Nach Finnl. Hydr.-Biol. Unters. No. 1.

**Summary.**

In the preceding pages I have treated the problem of the distribution of temperature and salinity in the Gulf of Finland with stationary currents. In Chapter I an approximate formula (5) for the horizontal, rectilinear, frictionless and stationary current is deduced from V. Bjerknes' circulation theory. If the angle of inclination between the horizontal plane and the isopycnic surfaces is inserted into this formula, this angle is approximately determined by the formula (6). Density being a function of the temperature and salinity, we get from these formulae a number of rules regarding the horizontal distribution of temperature and salinity with different currents, or, if we suppose a current to be produced in the first instance by the wind, with different winds.

In Chapter II I apply the formulae to a certain hydrodynamic state in the Gulf of Finland during the period 1st—8th July 1925. The distribution of temperature and salinity had been determined during the expedition of the Thalassological Institute. After having ascertained that the currents during the time in question could be treated as approximately stationary with an outward-flowing surface current and an inward-flowing bottom current, I show that the average inclination of the isopycnic surfaces according to the observations, agreed with the calculations founded on the formula (5).

The formulae (5) and (6) were also applied to some other special cases and to the normal distribution of temperature and salinity in the Gulf of Finland (Chapter III). Results agreeing satisfactorily with the theory were obtained throughout.

# A precise method for determining the first "winter" zone in cod scales.

by

**Michael Graham**, M. A.

## Introductory.

It has been the general practice in reading scales of cod and other fish to exercise judgment in distinguishing true "winter" rings or zones from false or secondary ones. Even WINGE (1915), who went so far as to measure the width of the sclerites along the radii of the cod's scale, and drew from these measurements a curve, writes (p. 15):—

> "In seeking to ascertain the age of any particular cod it is important to have some previous acquaintance with the general appearance of the scale curves. These may, as already mentioned, frequently exhibit peculiar, more or less pronounced minima, not representing any winter, but having their origin in some unfavourable period in the life of the fish, e. g. sickness, cold, or lack of food. These secondary minima can of course make their appearance at any point in the course of the curve, and can generally be recognised as such, especially with some experience to the normal appearance of the curves."

The difficulties in beginning the study of cod scales have led me to seek some precise distinction between true "winter" rings and secondary narrowings of the sclerites, so that my readings shall not depend at all upon my judgment, — for the authorities agree that the judgment of the inexperienced is unreliable. I believe that I have found such a distinction between the first "winter" zone and the irregularities which are found within it.

## Methods.

The scales were taken from the fish on a knife[1]). A number of scales from each fish were mounted on a glass slide. The smaller ones were run in a little water on to an albumen smear and allowed to dry. The larger ones were cleaned and mounted in glycerine-jelly. Ten or more clear scales on each slide were usually examined before one was selected

[1]) Usually from below the first or second dorsal fin near the lateral line.

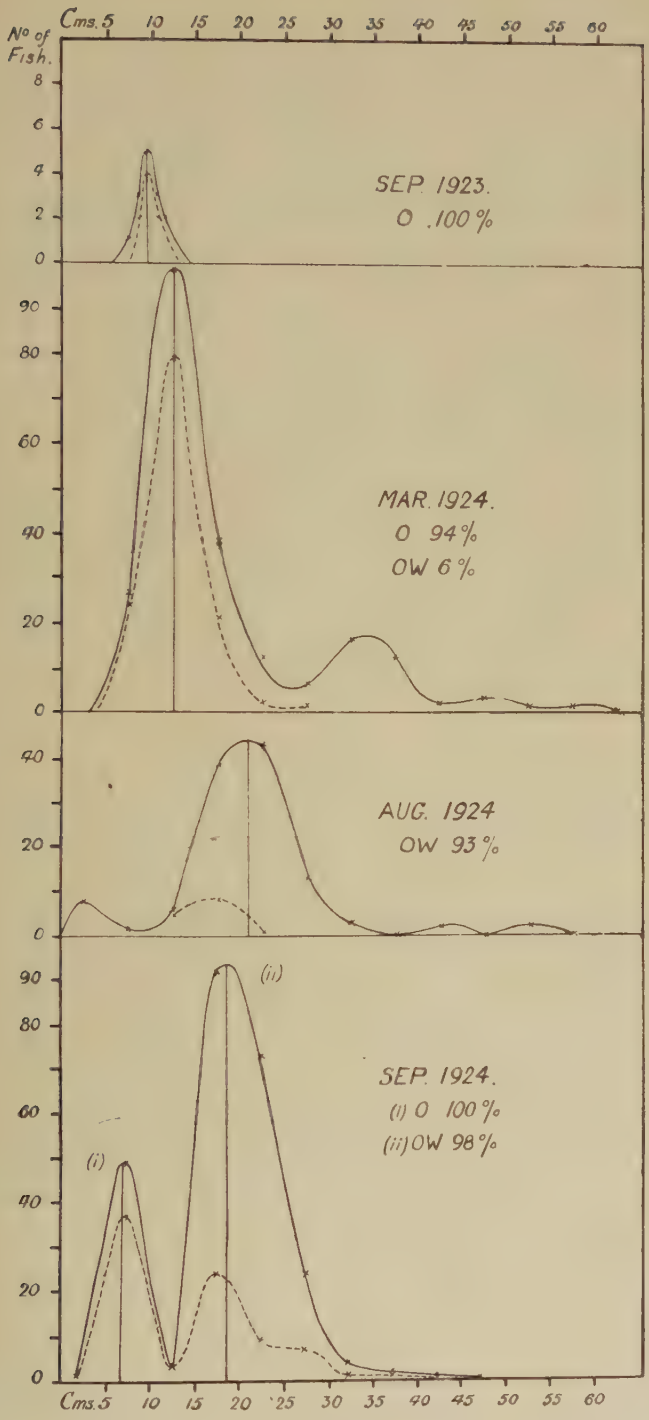


FIG. 1.

——— Fish caught  – – – – Scale samples

The Length Distributions of the Samples used in the Text.

as typical of the fish. In a very few cases only five were so examined. In this selection of the scale I used my judgment without any more precise method; but that is the only step in the process which would not be followed exactly and inevitably by another worker. Other things being equal the largest oval shaped and regularly marked scale was selected. As WINGE and others have described, the upper surface of the scale consists of a number of sclerites or platelets arranged in concentric zones, each zone having approximately the same shape as the margin of the scale. The selected scale was projected on to ruled paper and marks were made on a radial straight line from the centre of the scale to the margin, on or near the long axis. Every sclerite has on its outer tangential edge a raised ridge. I made a mark on my radial line at the outside edge of this ridge. (Where the sclerites overlap this did not measure exactly one whole sclerite between my marks). In this way I obtained for each scale a strip of paper, with a number of marks on it, which I have called a "scale-tracing". So far the method does not differ essentially from WINGE's, although he measured each sclerite with a micrometer eye-piece.

**Data.**

The material used up to now consists of samples of scales taken on four voyages of the Research Vessel "George Bligh". Not all the cod taken were preserved for age-determination. In Figure 1, I shew the lengths of the fish taken and the lengths of the fish of which I have examined the scales. The samples were taken before I started the investigation proper, which accounts for the fact that they are not complete collections of all the cod taken. The reason why they have been used, rather than samples taken subsequently, is that in 1925 I was concerned with collecting fish of slightly greater lengths, and on the grounds where I found these abundantly I did not encounter the very small fish.

A uniform method was used to draw the smooth frequency curves in Figure 1. The numbers of fish in each 5 cm. length group were plotted as ordinates and intermediate points interpolated by WOLLASTON's method (1926).

The lengths of the samples fall naturally into definite groups. These will be referred to as follows:—

"September, 1923". The group having its mode near 9.5 cms.
"March, 1924". The group having its mode near 12.5 cms.
"August, 1924". The group having its mode near 20 cms.
"Sept. 1924, (i)". The group having its mode near 7 cms.
"Sept. 1924, (ii)". The group having its mode near 20 cms.

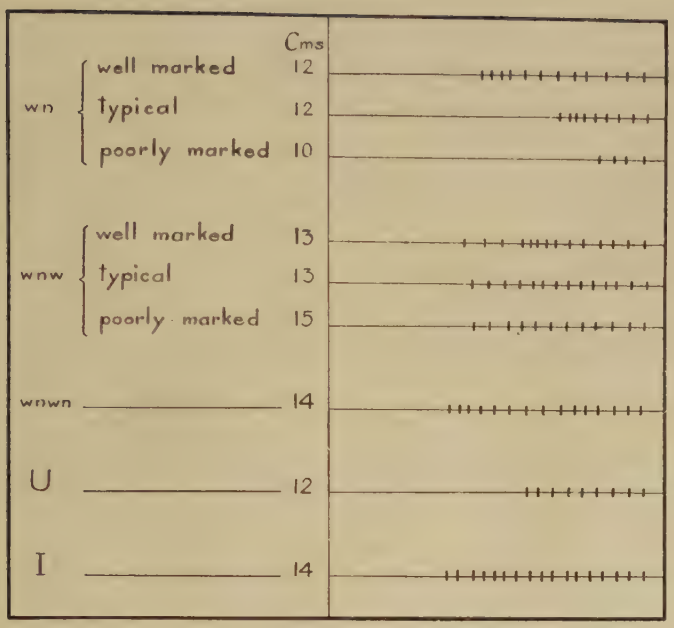


FIG. 2.

Illustrating the first classification (by personal judgment) of scale-tracings from the length-group "March 1924" The centre plate of the scale is off the diagram to the right in each tracing.

wn - a wide zone inside a narrow.
wnw - an additional wide zone outside wn.
wnwn - an additional narrow zone outside wnw.
U and I - scales not read owing to uniformity and irregularity.

The reproduction is approximately accurate.

### The Reading of the Scale-Tracings.

When I examined tracings from "March, 1924" I found that without any measurement at all, and without any ambiguity, 71 % of them shewed one zone of narrow sclerites. Of the remaining 29 %, 11 % seemed to shew two narrow zones and 18 % were unreadable, either because they were too irregular or because they were too uniform. The 71 % which shewed one narrow zone was made up of 24 % shewing a narrow zone outside a wide one and 47 % shewing apparently an additional wide zone outside the narrow one.

In Figure 2, I have reproduced some of the tracings to shew the characteristics of these two classes, and a few of the irregularities. The "typical" tracings were selected by judgment only.

Table. Classification of samples of Cod Scales according to the use of the Criterion applied to the Scale-tracings.

| cm. length | Sept. 1923 | March 1924 | | | Aug. 1924 | | Sept. 1924 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (i) | (ii) | |
| | O | O | OW | OWn | OW | OWNW | O | O | OW |
| 0 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 2 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 3 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 4 | .. | .. | .. | .. | .. | .. | 1 | .. | .. |
| 5 | .. | .. | .. | .. | .. | .. | 3 | .. | .. |
| 6 | .. | .. | .. | .. | .. | .. | 7 | .. | .. |
| 7 | .. | 3 | .. | .. | .. | .. | 16 | .. | .. |
| 8 | 2 | 4 | .. | .. | .. | .. | 10 | .. | .. |
| 9 | 4 | 17 | .. | .. | .. | .. | 1 | .. | .. |
| 10 | 2 | 19 | 1 | .. | .. | .. | 1 | .. | .. |
| 11 | 2 | 23 | 1 | .. | .. | .. | .. | .. | .. |
| 12 | .. | 17 | .. | .. | 1 | .. | .. | .. | .. |
| 13 | .. | 6 | 1 | .. | 2 | .. | .. | .. | .. |
| 14 | .. | 10 | 1 | .. | 2 | .. | .. | .. | 2 |
| 15 | .. | 4 | 1 | .. | 5 | 1 | .. | 1 | 5 |
| 16 | .. | 4 | 1 | .. | 2 | .. | .. | .. | 5 |
| 17 | .. | 4 | 1 | .. | .. | .. | .. | .. | 2 |
| 18 | .. | 6 | .. | .. | .. | .. | .. | .. | 4 |
| 19 | .. | .. | .. | .. | .. | .. | .. | .. | 7 |
| 20 | .. | 1 | .. | .. | .. | .. | .. | .. | 3 |
| 21 | .. | 1 | .. | .. | 1 | .. | .. | .. | 1 |
| 22 | .. | .. | .. | .. | .. | .. | .. | .. | 2 |
| 23 | .. | .. | .. | .. | .. | .. | .. | .. | 3 |
| 24 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 25 | .. | .. | .. | (1) | .. | .. | .. | .. | 2 |
| 26 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 27 | .. | .. | .. | .. | .. | .. | .. | .. | 2 |
| 28 | .. | .. | .. | .. | .. | .. | .. | .. | 2 |
| 29 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 30 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 31 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 32 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 33 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 34 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 35 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 36 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 37 | .. | .. | .. | .. | .. | .. | .. | .. | (1) |
| 38 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 39 | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Total | 10 | 119 | 7 | .. | 13 | 1 | 39 | 1 | 42 |
| Percentage of Length-group | 100 | 94 | 6 | .. | 93 | 7 | 100 | 2 | 98 |

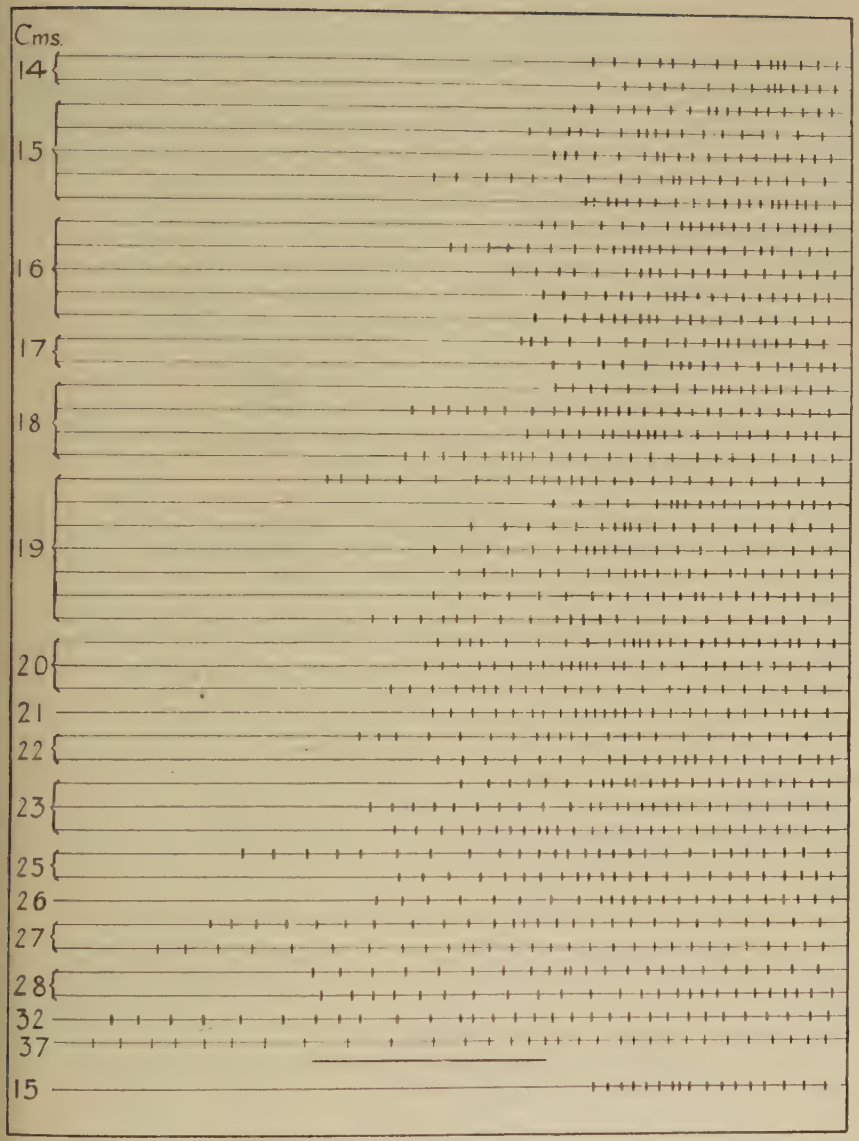


FIG. 3.

Reproduction (approximately accurate) of Scale Tracings of Group Sep. 1924 (ii). All these were placed by the criterion in the Class OW except the last which was classed O.

When, however, I came to examine the groups "August, 1924" and "September, 1924 (ii)" I found a phenomenon that I had only observed in a very few of the group "March, 1924". This was a very great change in size between the sclerites in the narrow zone and the sclerites in the wide zone outside it. This is shewn in Figure 3. There is more than one way of measuring the change; but I think I have chosen the simplest. In nearly every tracing the sum of the widths (measured on the radius of the scale) of the narrowest pair of adjacent sclerites in the narrow zone was less than the width of the widest sclerite in the wide zone outside it. My method, so far as it is developed, consists in applying this as a criterion and calling a scale shewing this feature once OW. A scale shewing no narrowing so marked is classed 0.

If two narrowings allowed by the criterion are shewn, the scale is *provisionally* called OWNW and so on, adding an "n" if the margin appears to be narrow.

In the table is shewn a classification of each group on this basis. There are two fish whose length leads one to believe that they do not belong to the length-group with which they occurred. These are an OWn of 25 cms. in March, 1924, and an OW of 37 cms. in September (ii), 1924. These are omitted from further discussion.

It will be observed that scales in the Class 0 make up the whole group "September, 1923", 94 % of the group "March, 1924", and the whole group "September, 1924 (i)".

The class OW comprises 6 % of the group "March, 1924", 13 of the 14 in group "August, 1924", and 98 % of the group "September, 1924 (ii)".

## Interpretation of the Results.

It is impossible to examine here all the evidence on the age of the samples of fish, as deduced from their lengths. Similar deductions are discussed in detail by Russell (1922). We may, however, safely say that the groups "September, 1923" and "September, 1924 (i)", with modes at 9.5 and 7 cms., are 0-group fish[1]). Equally the groups "August, 1924" and "September, 1924 (ii)" are too long (21 and 19 cms.) to be 0-group fish, and this is borne out by the "March, 1924" group shewing an intermediate stage with a mode of 12.5 cms. Russell, p. 47, cites Fulton and D'Arcy Thompson, who used the length modes for age-determination and Heincke and Maier who used otoliths and bones, all of whom

[1]) I am here relying on previous work cited by Russell, p. 42, and on data submitted in a paper of my own — Fishery Investigations. Series II, Vol. VIII, No. 6, pp. 12, 24, 25.

give a slightly greater mode than that of the "September, 1924 (ii)" or "August, 1924" groups for the length of the I-group in summer or autumn. Therefore it seems fairly certain that these groups cannot be II-group fish[1]). It seems probable that the only II-group fish measured were not scaled, namely, those with a mode near 35 cms. in March, 1924. This agrees with previous work -- *vide* Russell, p. 48. Therefore it is almost certain that the groups "August, 1924" and "September, 1924 (ii)" were I-group fish, and the group "March, 1924" (mode 12.5 cms.) fish changing from the 0 to the I-group.

This enables us to examine the criterion that is to distinguish the first "winter" zone from irregularities within it. The class 0 becomes the 0-group and the class OW the I-group. Scales in the groups "September, 1923" and "September, 1924 (i)" are not sufficiently developed to shew secondary rings; so they cannot be used in judging the success of the criterion. Omitting these we find that the use of the criterion has placed 181 fish out of 183 fish examined in their correct age-group. This amounts to 99 %.

The practical application of the criterion is very simple. The width of the narrowest pair of adjacent sclerites in the innermost suspected narrow zone is taken on dividers and fitted to the width of the widest sclerite in the adjacent wide zone outside it. If the dividers fall within it, the narrow zone is the first "winter" ring. If they span or straddle the wide sclerite, the criterion rejects the suspected narrow zone. This can be done on the projection itself; there is no need to draw the tracing. My projection system magnified about 100 diameters.

It is hoped that it may be possible to extend a modification of the method, to the second and subsequent "winter" rings.

In conclusion I must thank Dr. E. S. Russell and Mr. H. J. B. Wollaston, who particularly, among several of my colleagues, have advised me in this work.

## Appendix.

Since writing the above I have read Dannevig's paper (1925), which throws serious doubt on the validity of the term "winter-zone". In the foregoing account, and for the *first winter*, no reason emerges for

[1]) I have purposely omitted Damas' conclusions, cited by Russell p. 48, since they are partly based on scale-readings and my present purpose is in a sense a justification of scale-readings. They are, however, that the cod in the North Sea reaches in general during the first year a length of 12—15 cm.; that its growth during the second year amounts to 12—15 cm., during the third, fourth and fifth years to about 10 cm. per annum, and after that to 8—10 cm.

relinquishing the term when the zone is restricted by the criterion. But inspection of the 44 tracings shewn in Fig. 3 lends a measure of support to DANNEVIG's hypothesis. My scale-tracings are strictly comparable with the marks on the abscissa axis of his graphs, except that, as shewn in his Fig. 5, he adds any gap between sclerites to the sclerite inside it, while I have added the gap to the sclerite outside it. Since gaps are infrequent, and do not differ greatly in radial width one from another, this is probably insignificant.

**Resumé.**

Il est possible de déterminer avec précision, sans avoir recours au jugement individuel, la première zone de petits sclérites ("zone hivernale") dans les écailles du cabillaud.

Ceci s'effectue par la comparaison exacte entre les largeurs radiales des sclérites dans la première zone hivernale et les largeurs des sclérites dans la zone de l'été suivant.

Cette methode, fort simple, a donné l'age juste en 99 pour cent des 183 individus des groupes I et II.

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# Correspondence.

To the Editor of "Journal du Conseil":—

In No. 3 of the "Journal du Conseil" I see that experiments with the preservation of fishing-nets are taken up in England and that copper-salts and resin are used with good results; in 1895 I began, helped by the chemist Professor Dr. E. Koefoed, similar experiments, and in 1899 "Dansk Fiskeriforening" arranged to have such a copper-oleate made and sold to the fishermen. Later about 1900 a factory undertook the fabrikation of this substance and called it "Virit", because it was a green substance. Some years later another factory undertook the manufacture and called the stuff "Cuprinol", because it contained copper.

This "Cuprinol" is used for sails, tents, wood, fishing-nets. It is used by our army and many private men recommend it; so this matter of preserving by means of copper-oleates is an old thing in Denmark.

August 1926.

C. G. Joh. Petersen.

# Reviews.

Schulz, B. Aerologische und Hydrographische Beobachtungen der Deutschen Marine-Stationen während der Kriegszeit 1914—1918.

Heft I. Hydrographische Untersuchungen. *A.* "Die periodischen und unperiodischen Schwankungen des Mittelwasserstandes an der flandrischen Küste (Oktober 1915—September 1918)". Deutsche Seewarte, Hamburg, 1920.

Heft II. Hydrographische Untersuchungen. *B.* "Beiträge zur Kenntnis der Gezeiten an der flandrischen Küste und auf der unteren Schelde".

**From the Foreword by the Deutsche Seewarte.** During the War there were active in middle Europe, a very large number of meteorological stations — especially "aerological" stations established by the military and naval authorities. The observations made by them constitute material not likely to be paralleled for a very long time. Hence it was necessary in the interests of Science to report upon them. With the means assigned to it by the State, the Deutsche Seewarte undertook the work. The Seewarte had at its disposal the organisation of the German naval stations; it had also a branch in Bruges which was later absorbed into the Marine Corps' observatory in Ostend. The D. S. decided to publish the results from the stations in a series of numbers which should form a special publication. The question of publication costs being acute, only the most important features of the meteorological work were to be dealt with — the kite ascents. These, it was decided to publish in extenso but in as condensed a form as possible. The whole work of the stations was to be published in a series of numbers which should record the following activities:—

Hefts 1 and 2 — Hydrography researches.
— 3 — 4 — Kite ascents on the German and Flemish coasts.
— 5 — 7 — Meteorological observations in Flanders (Wind, Temperature and Humidity).
— 8 — 9 — Kite and Pilot baloon ascents on the German coast.

The works before us are Hefts 1 and 2 of this series.

In Heft 1 Professor Schulz sets himself the following chief questions:—

1) To ascertain what are the fluctuations in mean water level on the Flanders coast. Full information was already possessed in the cases of the Dutch, German, and Danish North Sea and Baltic coasts, but about the Flemish coast little was known.
2) To ascertain to what extent the high tide level on the Flemish coast depends upon:—

a) The local winds without regard to atmospheric pressure.
b) The atmospheric pressure alone.
c) The local wind alone — after eliminating atmospheric pressure.

He finds:—

That the yearly fluctuation in mean water level increases from the Flemish towards the Dutch coast — this characterised the individual years of observation 1915, 1916, 1917 and their average.

That the half yearly period fluctuation of mean water level (which in the Eastern Baltic predominates over the yearly period, and which in the Western Baltic and the North Sea becomes less pronounced as we go from East to West) disappears almost entirely on the Flemish coast.

That during the period 1915—18 there was an important third and fourth yearly period.

That the dependence of sea level at Ostend and Zeebrugge on the wind prevailing at the time is expressible as an equation.

That the effect of the local winds on sea level is not seen until after the lapse of a varying time — on the average three hours.

That the relationship between sea level and the wind prevailing during the preceding three hours can be expressed in the form of an equation.

That a variation of 1 mm. in barometric height causes a corresponding change in sea level of 10.3 mm.

That one can express the dependence of sea level at Ostend and Zeebrugge on the prevailing wind during the previous 3 hours, after eliminating the effect of atmospheric pressure — by means of equations.

That as a result of the trend of the coast, onshore winds cause a greater piling up of water at Zeebrugge than at Ostend.

That the influence of the winds on the water level (in keeping with the known effect of earth rotation) has its effect to the right of the wind direction.

That the wind's influence on the water level varies approximately with the square of its velocity.

Equations are given connecting sea-level at Ostend and Zeebrugge with the direction and force of the winds:—

a) at the time,
b) over the preceding 2 hours,
c) do. after eliminating the effects of atmospheric pressure.

In Heft 2 Professor Schulz sets himself the task of elucidating the tidal phenomena off the Flemish coast and the tidal currents in the lower Scheldt. He uses material collected in Ostend and Zeebrugge. From 1915 to October 1918 tide gauge records were collected at these two ports; at first they were tide pole readings but after a few months two self registering gauges were used. For the whole period an unbroken series of records was available. The information obtained from the records was as follows:—

(i) An unbroken series of hourly sea-level readings.
(ii) Fundamental data as to the tidal phenomena and their dependence on the Moon's age and on meteorological factors.

All workers on marine currents must at some time have wished to be possessed of means which would enable them actually to follow the movements of freely floating bodies set adrift in the sea; such a study would appear to be an ideal one. Professor Schulz gives records of such experiments and they are of very great interest indeed. The "Schwimmkörper" used consisted in essence of four stout boards (2 metres by $^1/_2$ metre) pinned together in box fashion; other boards diagonally placed within the square so formed, carried on four thin legs a light mast (some 2.1 metres high) suitably painted and provided with a top mark. The whole structure was weighted with iron plates to ensure its riding well in the water. These objects were set afloat and their movements were followed and recorded by the highly trained personnel of the German shore batteries whose "long base line" range finders proved extremely useful. It was found possible to keep the floats in view up to 15 km. from land — in one case a float was clearly seen when 22 km. offshore. In a series of tables and charts, details of the movements of the floats are given. By means of these floats the currents off the Flemish coast were satisfactorily investigated, and information as to the influence of the wind and the topography of the sea floor obtained. In several cases it was possible to evaluate the residual current.

The work contains a mass of valuable information regarding the tides in the region concerned and cannot fail to be of immense service, for it seems unlikely that such intensive and extensive observations can be looked for except under very special circumstances.

J. N. C.

B. Schulz. Bericht über die Fortschritte der Ozeanographie 1915—24. Geographisches Jahrbuch, Band XL, Gotha 1926.

This report is an amazingly full digest of oceanographical literature which appeared during the period in question, and all workers will be grateful to Professor Schulz for having provided them with such a valuable record. During the years comprehended, the science has lost several eminent men by death:— Max Groll (author of the Bathymetrical Chart of the Oceans), Rollin Harris (author of "Manual of Tides"), the Prince of Monaco, and Wilhelm Brennecke.

Professor Schulz's task has been especially difficult in that he has had to treat within the same space, the publications issued during a term of years double that which was dealt with in the last corresponding report.

He hopes that he has been able to take cognisance of all noteworthy literature, but asks that any corrections and supplements should be sent to him addressed to the Deutsche Seewarte. The report is divided into the following sections and sub-sections:—

I. General Part.

A. *General.*

(i) Bibliographies.

(ii) Accounts of Research Institutions and Cruises.

(iii) Expeditions.

(iv) General Oceanographical Publications.
(v) Comprehensive Reviews and Textbooks which have appeared.

B. *Methods and Instruments.*
(i) Sounding.
(ii) Physical and Chemical Researches on Sea Water.
(iii) Waves, Currents and Tides.

C. *Topography.*
(i) Depths and Shapes of Sea Floors.
(ii) Geology of Sea Floors.
(iii) Sea Level.

D. *Sea Water.*
(i) Temperature.
(ii) Salinity and Gas Content.
(iii) Tint.
(iv) Evaporation.
(v) Ice.

E. *Water Movements.*
(i) Currents.
(ii) Tides.
(iii) Waves.

II. Specific Researches.

A. *Pacific Ocean.*
(i) Topography.
(ii) Temperature and Salinity.

B. *Indian Ocean.*

C. *Atlantic Oceans.*
(i) The whole ocean and the South Atlantic.
(ii) North Atlantic.
(iii) Areas connecting with the North Atlantic.
a) Mediterranean Sea.
b) North and Baltic Seas together.
c) North Sea.
d) Baltic Sea.

D. *Antarctic Sea.*

Professor SCHULZ deals briefly with the work which has been done under these heads and gives full references to the original literature.

J. N. C.

HARDY, A. C. The Herring in Relation to its Animate Environment. Part II. Report on Trials with the Plankton Indicator. — Fish. Invest. Ser. II, Vol. VIII, No. 7 1925 (1926).

It is a pity that Mr. A. C. HARDY's studies on the food and feeding habits of the herring have come to an end — at least temporarily — owing

to his appointment to the "Discovery" Expedition. He has prepared the present paper to report on some of his experiments which he has had to discontinue.

It has been said both by naturalists and fishermen that the occurrence of herring or mackerel is influenced by the presence or absence of different kinds of plankton. When shoals of *Calanus* or other copepods are present, usually rich catches of herring are to be expected. On the other hand when much phytoplankton (especially diatoms) fills the water — what the British fishermen call "weedy water", "stinking water" — no succesful fishing is probable.

If there is any truth in this saying, it would be of the utmost importance for the fishing vessels to know the plankton conditions before shooting their nets. The idea of Mr. HARDY was, therefore, to construct a simple and easily handled instrument to be used by the fishermen to obtain a preliminary knowledge about the plankton conditions.

Such an instrument is described in the present paper under the name of "plankton indicator". It is a cylindrical tube with a conical piece at each end and inside the rear cone is a disc on which a small piece of silk gauze is placed. (For more detailed information of the construction the reader is referred to the paper itself). The instrument is towed behind the ship for a short time, then hauled on board and the disc removed for examination.

By means of this instrument Mr. HARDY has had experiments carried out by different steam drifters in the North Sea and the English Channel.

The paper contains a report on the preliminary results obtained by these experiments; they do not give any definite answer on the question whether there is any direct correlation between the quantity and quality of the plankton and the quantity of herring or mackerel fished. But they contain some information which points towards such a correlation and other results which seem more complicated. The author sums up his results in the following sentences:—

1) For herring a green or even pale green disc (due to diatoms or *Phæocystis*) appears to indicate water in which fishing is likely to be poor.
2) In the spring mackerel fishing in the south-west there is an indication that when the disc is quite free from copepods, fewer mackerel are likely to be caught than when there are copepods present in even very small numbers. But the difference in appearance of a disc with only a few copepods on it and a blank disc is not sufficient to form a practical indication for the fishermen.
3) In the summer herring fishing off Shields there is definitely no general correlation between the quantity of plankton and the catch of herring.
4) At certain seasons an approximate correspondence on a larger scale exists between the quantity of copepods and fish (herring or mackerel) present in a particular region.

As the author himself states the trials are only few, and he hopes that they may be continued by other workers and at other places. This hope has the warmest support by the reviewer.

C. H. OSTENFELD.

G. O. Sars. Copépodes particulièrement bathypélagiques provenant des campagnes scientifiques du Prince Albert Ier de Monaco. Résultats des campagnes scientifiques accomplies . . . . par Albert Ier Prince Souverain de Monaco. Fasc. LXIX, Planches I—CXXVII, Monaco 1924—25.

In these two volumes, text and plates, Prof. Sars gives us his long expected review of the pelagic Copepoda taken over a long series of years on the various cruises carried out by the late Prince of Monaco in the Atlantic and the Mediterranean. Preliminary lists and brief descriptions of new species have been published by the author from time to time during the last twenty years in the Bulletins of the Monaco Museum and the Institut Océanographique, and this final account will be very welcome to all workers at the group.

The present work deals with the sub-order Calanoida, which includes a large majority of the pelagic species, and contains ample figures and descriptions of almost every species mentioned with the exception of some well known forms, many of which have already been figured in the author's »Crustacea of Norway«. A subsequent volume dealing with the remaining sub-orders Harpacticoida and Cyclopoida is promised.

The total number of species recorded is 296 and about two fifths of these are now fully described and figured for the first time. The bulk of the collection, including most of the new species, was taken with townets of a comparatively large mesh (Filet Richard à grande ouverture) in the deep water of the North Atlantic. Species of less than 2 mm. in length appear to have escaped capture or are represented by a few records in the case of the commoner forms. This selection, if not allowed for, might lead one to doubt the common belief that the Copepoda are mainly minute or microscopic forms, for among the species mentioned lengths of 5 or 6 mm. are frequent and several reach a length of 10 or 12 mm. or even more. When these great depths are explored with fine meshed nets the task of working out the collections will, it may be surmised, be a formidable one. As the author has already pointed out, many of the new species are only represented by one or two specimens, even in this extensive collection, a clear indication that this field for exploration is far from being exhausted.

The plates are reproduced directly from the author's drawings and it is needless to say that they reach the highest standard of faithfulness and artistry. Other illustrators of the Copepoda may have equalled Prof. Sars in accuracy but none has succeeded as well as he in catching the characteristic attitude of the animals which he figures.

In addition to the descriptions and figures, questions of synonomy and records by other writers are fully discussed and the distribution of each species briefly summarized. Taken in conjunction with the »Crustacea of Norway« the work forms a comprehensive and indispensable guide to the Copepoda Calanoida of the North Atlantic.

G. P. F.

R. E. Savage. The Plankton of a Herring Ground. Ministry of Agriculture and Fisheries. Fishery Investigations. Ser. II. Vol. IX. No. 1. 1926.

In this paper Mr. Savage gives an account of an investigation with Nansen nets (horizontal, surface, midwater, and bottom hauls) of the plankton of an area off the coast of Northumberland, in July 1922, in an attempt to discover the cause of failure of the herring fishing in that locality.

The plankton on the fishing grounds consisted mainly of Copepoda the predominant species being *Temora longicornis*, with over 63 percent by number of the Copepoda, *Calanus finmarchicus* being next with over 18 per cent. Other species in evidence were *Sagitta*, *Limacina*, *Oikopleura* and *Nyctiphanes Couchi*, which was present in numbers which must be regarded as considerable for townet collections. Larval Decapods, which were plentiful on the shallow water stations between Lowestoft and the fishing grounds, were comparatively scarce on the grounds. The fauna of the grounds in its general composition agreed very well with that recorded by Hardy from the stomachs of North Sea herring during June and July.

Not much light is thrown on the main object of the investigation, namely the cause of the poor fishing, owing no doubt to lack of information as to the normal conditions. It is suggested however that the scarcity of the Copepod plankton may have been the reason, or possibly restricted vertical migration, the herring not rising into the upper layers in which the plankton was poor.

Some interesting tables have been compiled showing the differences of distribution of the plankton in the different layers of water during the hours of night and darkness. Some of the Copepoda gave clear indications of vertical movements, e. g. *Temora*, which was most plentiful at the bottom during the day and moved upwards to midwater and, to a small extent, to the surface during the night. *Calanus* which was also more plentiful at the bottom by day doubled its numbers at midwater during the night without any noticeable increase at the surface, and *Pseudocalanus*, also a bottom form by day, became definitely most abundant at the surface by night. The author compares his results with those recorded from off Plymouth by Russell (in a paper reviewed in Vol. 1 No. 1 of this Journal) pointing out some apparent discrepancies which he, rightly no doubt, puts down to the want of sufficient data.

A note on the change of colour of the plankton from red through pink to white, on a line of stations running eastwards from the fishing grounds, while the composition of the plankton remained the same suggests a subject for investigation which might give interesting results.

G. P. F.

J. Pavillard. Report on the Danish Oceanographical Expeditions 1908—1910 to the Mediterranean and adjacent seas. Vol. II. J. 4. *Bacillariales*. With 116 text-figures. Copenhagen. Dec. 15. 1925.

This is an important contribution to our knowledge of the Diatom Flora of the Mediterranean region. Though chiefly a taxonomic study, based on the examination of over one hundred and fifty samples obtained

during two cruises in the summer and winter respectively, the results are of considerable significance in relation to phytogeographical problems.

From the Mediterranean and the adjacent Atlantic a total of one hundred and eighteen species of marine Diatoms are listed of which however fifteen were not present in the samples here studied. These latter include the northern *Asterionella japonica*, and *A. notata* and *Chaetoceras anastomosans*.

Two new species are here described namely *Coscinodiscus Thorii* and *Coscinodiscus Alboranii*. The former appears to be generally distributed in the Mediterranean during the winter period whilst the latter would seem to be essentially a summer species.

Of the species already known to science perhaps the most interesting is the record of *Rhizosolenia firma* originally described by KARSTEN from a single fragment found in the Indian Ocean. In the Mediterranean material this species was present in three samples from three separate stations in the Tyrrhenian Sea and all collected during the winter cruise. Another rare species *Spatangidium arachne*, known from a few specimens from the Indian Ocean and the Gulf of Lyons, was found in some quantity in the Sea of Marmora. This is in harmony with the occurrence of *Antelminellia gigas* which is present in the tropical Atlantic and throughout the Indian Ocean: a distribution that recalls the discontinuous range of many algae to which SVEDELIUS has drawn attention (Archiv für Botanik 1924) and which may be the result of the past distribution of land and sea.

Other species of the tropical Atlantic are *Gossleriella tropica*, *Schröderella delicatula* and *Rhizosolenia indica*; the last named being also present in the Indian ocean.

The boreal element is represented by *Thalassiosira nordenskiöldii* and *Coscinosira polychorda*, whilst amongst endemics mention may be made of *Dactyliosolen mediterraneus* and *Bacteriastrum biconicum*.

One of the most abundant species was *Bacteriastrum delicatulum*, of widespread occurrence also in the temperate Atlantic, whilst one of the most regular constituents of the diatom flora is *Rhizosolenia calcaravis* which exhibits an increasing frequency as we pass from the western Mediterranean to the eastern seas.

From these collections it would appear that the diatom flora of the central Mediterranean, as represented by the Thyrrhenian Sea, is much richer in species than its western part near the Straits of Gibraltar.

E. J. SALISBURY.

DANNEVIG, ALF. On the Growth of the Cod and the Formation of Annual Zones in the Scales. Report on Norwegian Fishery and Marine Investigations. Vol. III. No. 6. pp. 23. 77 graphs. 4 figs. 28 photos of scales. Bergen 1925.

This paper must be read by everyone who investigates scales.

Dr. DANNEVIG placed a number of 0-group codling in the rearing pond at Flødevig in October 1919, and examined samples in the course of the following three years. The temperature in the pond agreed closely with

that of the sea at one meter's depth outside — having its maximum from June to August and its minimum in February. The cod were fed in October and November and the first part of December, 1919; but from the middle of December till May 1920 they had to hunt their own food in the fauna of the pond. They were fed in the summer of 1920, but feeding was discontinued on the formation of ice in the autumn — "and in the same way the following year".

Scales from three fish were examined in March 1920, from 48 fish in May and June 1920, from 3 fish in the winter of 1920—21, from 3 fish in October 1921 and from 3 fish in May 1922.

Of the first three (taken from the pond in March 1920) two shewed a considerable zone of wide platelets at the outside of the scale.

From inspection of Dr. DANNEVIG's graphs it can be seen that of the 48 examined in May and June, 27 shewed a well-marked[1]) wide zone on the outer part of the scale, 12 of these clearly having a few narrower sclerites at the extreme edge, and nearly all shewing some reduction. In the remaining 21 this wide zone was not so well marked, and was not shewn at all in some of the smaller fish.

Three specimens from the winter 1920—21 shewed large sclerites near the edge and two minima, although the age of two years was not reached until the spring of 1921.

In October 1921 three specimens shewed three minima although the fish were only $2^1/_2$ years of age — and small sclerites at the margin.

In May 1922 three fish shewed three minima in the scales, "the last one at a considerable distance inside the margin".

Fast growth was found to correspond with the formation of wide sclerites.

Dr. DANNEVIG's hypothesis to account for these facts is that the small sclerites are laid down in the summer and the large in the winter — the reverse of the accepted view. This hypothesis is offered tentatively by its author since the conditions were not quite natural, but he suggests that the term "winter-zone" must be abandoned.

It should be observed that the fish in the samples of May and June 1920 which did not clearly shew wide sclerites in the outer part of the scale, (10 at least), do not conform to the new hypothesis. Dr. DANNEVIG shews that these are the smaller fish and suggests that they, not the majority, are the abnormal individuals. His interpretation is that May and June are just after the end of winter, so that the wide sclerites shewn by the majority were put on in winter. But the wide sclerites may be accounted for on the old hypothesis, since summer has begun. The old hypothesis in its simple form does not, however, account for the formation of narrow sclerites at the extreme margin. The wide sclerites on the margin of the three scales in May 1922 conform to the old hypothesis, on the same interpretation.

It is clear that Dr. DANNEVIG does not wish to suggest that his hypo-

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[1]) A "well-marked" wide zone is here defined by the reviewer as one which, when compared with the narrow zone within it, satisfies the criterion suggested on p. 344 of this journal.

thesis is established: he states explicitly that he merely wishes to call the attention of scale investigators to his data. For this the reviewer and all others who have worked on cod scales must be exceedingly grateful; for all must have encountered the difficulties that there are in accepting the older theory rigidly, and the difficulties have not previously been described. It is not possible to examine Dr. DANNEVIG's data critically within the limits of a review, especially in regard to the sample of May and June 1920, of which several interpretations are possible. If, however, 38 of these are allowed as conforming to the new hypothesis rather than to the old, we may tabulate the evidence thus:—

| | Nos. of fish conforming to | |
|---|---|---|
| | The New Hypothesis | The Old Hypothesis |
| March 1920 | 2 | 1 |
| May & June 1920 | 38 | 10 |
| Winter 1920—21 | 3 | — |
| October 1921 | 3 | — |
| May 1922 | 3(?) | — |
| Total... | 49 | 11 |

There is a case for the new hypothesis, and no further age-determinations can be made with certainty until the hypothesis is established or relinquished.

At the same time it is well to remember (i) that DAMAS has shewn (R. et P. V. X) that well marked secondary summer rings occur in *G. virens* and *G. callarias*, (ii) that perhaps the absence of competition in the pond may have more than discounted the fact that the fish were not fed in the winter and (iii) that individual variation in scale structure is considerable. Consequently it is not impossible that these results may, since the numbers are small, be due to individual and unnatural emphasis of DAMAS' summer check, and individual and unnatural obliteration of the usual "winter" zone.

The author is to be commended for reproducing all his data (as graphs) and the photos are particularly clear.

MICHAEL GRAHAM.

N. L. TCHUGUNOV. Essay on the Quantitative Exploration of the Benthos-Production in the North part of the Caspian Sea and of the typical Basins in the Volga Delta. Reports of the Ichthyological Laboratory in Astrachan. Vol. V. No. 1. 1923.

This most instructive paper is written in Russian[1]), but a useful English summary is appended. In principle, PETERSEN's methods for the

[1] An English translation has been prepared by the Ministry of Agriculture and Fisheries, London.

quantitative estimation of food-values were followed, but with certain modifications in technique. Thus, 3 % formalin was used instead of alcohol for preserving animals taken in the bottom-sampler, a procedure which would seem, from the results of tests, to be an improvement in method. The values of the percentage content of dry matter, expressed in terms of the rough formalin weight agree fairly well, on the whole, with equivalent Danish estimates based on the rough alcohol weight, with one curious exception:— whereas Petersen gives the low value of 1.6 % for *Diastylis* sp., Tchugunov finds it to be as high as 21.6 % for "large" Caspian Cumacea, and 21 % for "small".

From his determinations of that part of the total dry-weight which may be regarded as dried organic matter, Tchugunov compiled a table of "food equivalence" for those species which are most important as food for Caspian fishes. This table, which in form resembles that of an American tournament, gives at sight, either the actual quantity of dry organic matter in one specimen of a particular food-animal, or alternatively, its equivalent in terms of numbers of other animals. For instance, the table shows that one "large" specimen of *Viviparus viviparus* contains 184.96 mgr. of dry organic matter, and is equivalent to 2.15 "medium" specimens of the same species, or to 6.46 "large" mysids or to 3406.26 "small" cumacea. Another table similarly arranged is based on the quantities of *total* dry weight per single specimen as distinct from the quantities of dry *organic* matter.

The whole region of the North Caspian covered by the investigations is distinguished by peculiar conditions of distribution of depth, soils and salinity. The last factor has a determining significance for the quantitative composition of the bottom-fauna in the "freshened" part of the sea adjacent to the Volga delta. Three definite zones can here be recognised:— 1) The Volga fresh-water estuarine zone; 2) The brackish-water zone, with two divisions, 2a) a low-salinity area of sand, mud and shells, and 2b) a rather more saline water zone with great depositions of mud; 3) The sea-zone where the water is of a permanently higher salinity, and the bottom shows a dominance of grey mud and shells. The animal life would seem to present a series of transitions from a predominance of fresh-water forms in the Volga estuarine zone, to a predominance of purely marine forms in the Sea-zone. The qualitative and quantitative differences in fauna consequent on the excessive variability of hydrographical conditions are most carefully considered by the author. Reference may be made to his observations on a periodic heavy mortality which occurs among the Cardiidae which live just within the sea-zone. During the months of July and August specimens taken from that district are in an apparent "anaesthetised" state with gaping valves and fully-extended siphons. They react but feebly to irritant stimuli, and it is thus possible to preserve them in an absolutely natural state. Tchugunov suggests that such a phenomenon could be caused by the combined influence of temporary strong "freshening" of the water, due to the spreading of flood-water from the Volga which occurs at the time, and of a marked increase in temperature up to 27°—30° C. which frequently takes place during the second half of the year.

The study of the general productivity of stations in the North Caspian

reveals the highly important fact that all the bottom-animals living in that area appear to be of direct value as food for fishes. In Danish waters, and elsewhere, a considerable proportion of the animal population consists of animals which are either useless as fish-food or, themselves, definitely predatory; but apparently, in the North Caspian, all the animals are consumable. This may account for the great and valuable fish-population to be found there. In an interesting discussion on the factors which may account for the high degree of productivity of the North Caspian, Tchugunov refers to the enormous quantities of detritus derived from the magnificent vegetation in the lower reaches of the Volga, which he regards as of prime importance to organic life, and comparable in significance with that formed from the great Zostera beds in Danish waters.

Further work of so careful a nature as that described in the present paper will be productive of further valuable knowledge of Benthos-production generally.

E. F.

H. Blegvad. Continued Studies on the Quantity of Fish Food in the Sea-Bottom. Report of the Danish Biological Station, XXXI, 1925.

Dr. C. G. Joh. Petersen's pioneer work with his bottom-sampler in Danish waters prepared the way for the systematic study of the quantity of fish-food in the sea-bottom. It is now possible to obtain a reasonable working estimate of the number and gross-weight of many important food-animals per unit of sea-floor, and hence, by comparison with the information gained by the examination of the stomach-contents of fishes, to draw sound conclusions concerning the value of an area as a feeding ground for fishes. Furthermore, Petersen's conception and definition of a number of distinct "animal communities" are of real assistance in the study of feeding and growth phenomena in different regions, whatever opinions may be held regarding the actual significance of the "communities".

Dr. H. Blegvad's work on the food of fishes in Danish waters, is, therefore, of more than local interest, for much of the knowledge he has acquired by this modern method of investigation is directly helpful to workers in other countries. In his introduction to the paper under review Blegvad states that "the bottom-sampler nearly always brought up the same animals of the bottom-fauna as were found in the stomachs of the fishes. It was however seldom that the same animals dominated by number and weight both in the contents of the bottom-sampler and of the stomachs. This depends upon the fact, that the fishes make a selection of the existing bottom-fauna, and not only a selection among the different species, but also among the different sizes of the same species". It may be argued, not unreasonably, that non-agreement between stomach-contents and "grab" samples might be due to the circumstance that the fishes had been feeding upon species for which the "grab" is not an efficient sampler. Thus, for example, according to Tchugunov, Mysidacea and Cumacea are of importance to fishes in the North Caspian, but "grab"-samples give an under-estimate of the density of occurrence of these forms. For small lamellibranchs, the grab is undoubtedly a highly efficient sampler, and

the discrepancy between the numbers in the stomachs of fishes, and those in the grab-sample is, therefore, a measure of the selection by fishes from among the different members and sizes of the lamellibranch population. If then, as seems the case in some of the inshore Danish grounds, lamellibranchs constitute the great bulk of the total bottom-population, an investigator may, with some degree of confidence, estimate the food-value of a ground solely on the evidence of grab-samples. On the other hand, in more distant open waters where lamellibranchs do not flourish, it may be necessary to employ more than one collecting instrument to ensure that a sound estimate of the available food has been obtained.

Dr. Blegvad has divided the sea-bottom animals of his district into two classes according to their suitability as food for the common food-fishes, plaice, dab, long rough dab, flounder, eel, cod, whiting and haddock. He includes in his report an interesting chart which illustrates very clearly the author's impression of that part of the total weight of bottom-animals per unit area which may be regarded as available fish-food, in various places populated by different animal communities. In his estimates, due allowance has been made for the changes in food-value of a species with increasing size and age. Thus, in the case of the lamellibranchs, the increasing thickness of shell with advancing size is of importance. For instance, the young of Mya are of general value as food, but the adults are useless except perhaps to eels and cod which sometimes bite off the siphons; — plaice in Danish waters appear to be unable to consume lamellibranchs which exceed about 3 cm. in length. Observations of this kind emphasise the fact that although grounds may be equally densely populated as regards the total number of animals, they may yet differ considerably in their value as a feeding ground for fish.

This paper also contains information regarding variations in quantity of fish-food from year to year. Good brood-years alternating with poor, for the chief food-species, play a great part in producing such variations. The consumption by fishes and other predatory animals is also of importance, although Blegvad is of the opinion that the effect of the consumption by fishes has been exaggerated. Great mortality among food-animals occurs, especially during the winter, the causes for which remain obscure, but it is suggested that such physical phenomena as cold and lack of oxygen may be responsible. In several instances Blegvad demonstrates a positive correlation between the variations in quantity of food and the yield of the flat-fish fishery; — in the Fur Sound—Risgaard Broad there is a marked coincidence between the quantity of *Solen pellucidus* and the yield of the flat-fish fisheries from 1915—1924. In other places, however, the one bears no relation to the other, nor, under the circumstances, would such a correlation be expected. In the Thisted and Livø Broad, the number of plaice transplanted from other areas varies from year to year; — a fact sufficient in itself to account for the non-agreement between the yield of the fishery and the quantity of food. The Nissum Broad is a pronounced "wandering place" from which plaice continually wander out into neighbouring broads, and to which they come in from the North sea; and here again there is little reason to expect agreement between the food supply and the yield of the fishery. E. F.

J. H. Orton & P. R. Awati. Modification by habitat in the Portuguese oyster (*Ostrea* (*Gryphæa*) *angulata*). Journ. Mar. Biol. Ass. (N. S.). Vol. XIV, pp. 227—30. 1926.

In this preliminary paper a comparison is made between a sample of Portuguese oysters from the river Blackwater, Essex, where they had grown in situ from larvae which had developed there, and other Portuguese oysters, partly such as had been directly imported from the Tagus beds, partly such as had after importation been relaid for a summer on English beds (at low water neaps).

It is stated that the Portuguese oysters having developed from larvae in deeper water in England are of greater length, the average ratio of length to height being 1 to 1.17; for the directly imported oysters from Portugal the ratio was 1—1.65 and for the oysters relaid in England 1-—1.69.

The authors do not as yet give any explanation of this. The reviewer would call attention to the fact that also in the native oyster a similar tendency seems to exist, specimens of *O. edulis* from the deeper beds of the North Sea always being described as broader than individuals from the Limfjord and the Dutch beds. The cause might eventually be looked for in the slighter movement of the water at the greater depths.

Further the information is given that the average growth-rate of the relaid Portuguese oysters was from March to October ca. 35 mm., and equal in both sexes. It is of interest to learn that oysters of "neuter" sex have a lesser growth rate (29 mm.), which serves to prove the connection between the development of sex products, nourishment and growth.

R. Spärck.

Ikusaku Amemyiya. Notes on experiments on the early developmental stages of the Portuguese, American and English native oysters, with special reference to the effect of varying salinity. Journ. Mar. Biol. Ass. (N. S.). Vol. XIV, pp. 161—175. 1926.

In the present paper the author has treated the effect of salinity on the pelagic larvae of the three oyster species occurring on the North Atlantic coasts, *Ostrea virginica*, *O. angulata* and *O. edulis*, that is to say only the early developmental stages have been subjected to investigation.

In good agreement with the experiences of earlier investigators it turns out that *O. virginica* is the species offering the best opportunity for a study of the developmental stages. The author has succeeded in feeding larvae of *O. virginica* with the flagellata *Pontosphaera Huxleyi* (size 2,5 $\mu$); the larvae lived until 14 days increasing somewhat in size without however reaching attachment.

The artificially fertilized eggs were developed at temperatures of 18°—21,5° C. in 24 different culture media with a salinity varying from 52 ‰ to 12,3 ‰. It turns out that development is only possible between 15—39 ‰; the favourable salinity is between 22 ‰ and 33 ‰, with optimum at 25—29 ‰. At the optimal salinity all fertilized eggs were developed and became normal larvae. At lower or higher salinity some eggs remained

undeveloped, and several abnormalities appeared; some of the blastomeres became isolated from the rest, giving rise to "partial larvae" etc. Too high or too low salinity further causes retardation of the development.

Larvae of *O. angulata* were treated in a similar way. It however appears that it is much more difficult to make the larvae of this species grow. Also here an uppermost and a lowermost limit of salinity for development are stated at respectively 43 ‰ and 21 ‰. The favourable salinity is between 25—38 ‰, optimum at 28—35 ‰. All these salinities are higher than those connected with *O. virginica*. The temperatures in these experiments were 20°—23,5° C.

Finally the author made similar experiments with *O. edulis*. These experiments were rather unsuccessful as the shell-larva stage was not reached, although other investigators have formerly succeeded in similar cases. The author however thinks the following limits of salinity may be stated for the earliest developmental stages: highest 45 ‰, lowest 24 ‰, most favourable 27—40 ‰, optimum 31—35 ‰. The temperatures at these experiments were 16,2°—18° C.

The temperature having varied for the different experiments 2°—3° C., it would have been of importance if the temperature had been stated in the paper for every single experiment. Possibly also the variations of temperature may have had some influence on the retardation of development. The author does not mention at all the presence of bacteria or other microorganisms in the cultures, to which certain of the above mentioned abnormalities probably may be due.

The author's results are however in the main correct, especially the extreme limits. It would however have been of great interest, if the author had made a comparison between the experimental results to which he has arrived and the information found in the literature concerning the limits of salinity within the range of distribution of the respective oyster species. As to *O. edulis* there seems to be the very best agreement between the results obtained and observations in nature. *O. edulis* f. inst. occurs in the Limfjord only in localities with a salinity as a rule exceeding 24 ‰.

R. Spärck.

J. H. Orton. On Lunar Periodicity in spawning of normally grown Falmouth oysters (*Ostrea edulis*) in 1925, with a comparison of the spawning capacity of normally grown and dumpy oysters. Journ. Mar. Biol. Ass. (N. S.). Vol. XIV, pp. 199—226. 1926.

The principal object of this investigation was to determine whether the socalled "dumpy oysters" are as good spawners as the normally grown oysters. By "dumpy oysters" are meant in England oysters with the shell deviating from those of normal oysters in being, among other things, higher than long, with the mantle-cavity wider than in normal oysters, the lines of growth closer and the umbo of the shell projecting dorsally to the hinge so as to form a pronounced beak, and finally the shell tends to be chambered. They differ also on other points, for instance the "dumps" show less tendency to be green, due to copper absorption by the leuco-

cytes. The author does not in this paper give any explanation of the causes by which the "dumpy oysters" arise; the reviewer may add that the "dumps" are rather frequent in the Limfjord where they occur in the inner parts of the fjord with a much varying and often low salinity (about 25 ‰). Thus there seems to be some connection in this respect. The influence of salinity on the growth of the shell seems to be a cause of importance.

A great number of oysters (3290 normal, 3392 "dumps") were examined. The percentages of "white-sick" were respectively 6,43 and 5,07; of "black-sick" 8,27 and 7,24, thus only slightly lower for the "dumpy oysters".

The author considers that he has established a lunar periodicity in the spawning. In the summer of 1925 there were on the beds of the Fal estuary three spawning periods, which occurred round about the days of full moon, and the author from this concludes that there may be a causative relation between the full moon and the spawning of the oyster.

In this connection the reviewer can confirm the existance of a periodicity in the spawning of the oyster. He has formerly pointed out (Rep. Danish Biol. Stat. XXX) that in the Limfjord a very short period likewise occurs, in which the very greatest percentage of the spawning oysters are found. As a rule we, however, meet with only one period there, as in the years 1919, 1920, and 1921. But in very warm summers, as that of 1925, we also had several, at any rate two such periods in the Limfjord. None of the periods of 1919, 1920, and 1921 coincided with the full moon. It is true, we have no tides in our Limfjord, and as the lunar periodicity must, most likely, depend on the tides, this periodicity may very well occur in English waters, although it is unknown in the Limfjord. The reviewer cannot, however, help thinking that the probability of a real causative relation seems only small. The coincidence of the spawning and the full moon, stated by the author, is, to begin with, rather irregular; as to the dumpy oysters no lunar periodicity has been established at all. Concerning the two first and greatest spawning periods, a coincidence with increasing air temperatures occurred (unfortunately we have no observations of temperature from the beds) so that it is very well possible that the true cause of the periodicity may be sought in the temperature. The reviewer will finally call attention to a third possibility, to wit, that the periodicity may be due to oysters of different year-classes spawning at different intervals. He believes that he has observed in certain marine Lamellibranchiata that the older individuals spawn at the beginning of the summer, the younger later on. Something similar to this might very well be supposed to take place in the oysters; the older oysters thus spawning during the first, the younger during the following periods. In cold summers only one group would have time to spawn, for which reason, as a rule, only one period occurs in the Limfjord. It is evident that if a species spawns periodically with the interval of ca. 1 month, the periodicity will in several years happen to become a "lunar periodicity" without, however, having any causative relation to the phases of the moon. That the dumps, which are undoubtedly slowly growing oysters with slightly marked year-classes, exhibit a less distinct periodicity even indicates that the question of the age of the individuals may be of importance in this

respect. The reviewer is far from denying that the phases of the moon may, through the tides in connection with other factors, exert an influence on the periodicity of the spawning, but as yet nothing definite has been proved in this respect. The author and the reviewer, however, quite agree in this that, as to a whole series of questions concerning the spawning of the oyster, more extensive experiments and investigations are needed.

R. Spärck.

E. Emrys Watkin, B.Sc. Investigations on Cardigan Bay Herring. Parts I & II. Rept. Mar. and Fr. Water Invest. Dept. Zool. Univ. Coll. Wales, Aberystwyth. Vol. I, pp. 5—21. Dec. 1925.

This account of the Herrings of the Welsh Coast deals firstly with a statistical examination of two samples of fish from Borth Bay in 1921, and secondly with a more general biological study of 13 samples from Borth, Aberystwyth and Newquay in 1922.

The "racial" measurements in Part I were those recommended by the Ministry of Agriculture and Fisheries in 1913, and along with these, the maturity and age of the fish have been studied.

The two samples were taken on the 15th and 25th of October, 1921 and in each the fish with 2 winter rings predominated; the gonads were mainly in stages IV, V and VI.

From the consideration of the data, Mr. Watkin concludes that there is a difference between these two lots of herring, the fish of the earlier sample being larger, age for age, than those of the later catch. When the various measurements are expressed as percentages of the length of the fish in each sample it is seen that the results are very similar, agreeing in some cases to the third decimal place. It is obvious therefore that there is no difference in the proportions of the fish, but only a difference in the actual size.

The author has made a series of measurements on the scales and so calculates the average length of the scale up to the formation of each winter ring, each year-class being treated separately. The result found is that the earlier sample of fish have a larger growth in their first growth period than those of the later lot. This is a common feature of the North Sea herrings and it probably represents a difference in the time when the two samples were spawned.

It is to be regretted that Mr. Watkin has not made his growth calculations comparable with the actual length of the fish, for it is of great value in connecting together the "whitebait" or 0-group fish with the adults.

In the second part of this paper the age, growth, length and maturity of the herrings of Cardigan Bay from October—January 1922, have been observed. The catches were all made very near the coast and consist of different shoals of fish, as can be seen from the maturity tables. The 4 and 5-year old fish form the main part of this fishery but at times, possibly owing to the proximity to the coast, these year groups are out-numbered by fish with one and two winter rings on their scales.

These younger herrings are maturing for the first time and are obviously

on a spawning migration, but the main Aberystwyth fishery seems to be dependent on fish which have spawned some time previously.

It was found that the growth of these fish up to the formation of the first winter-ring could be classified as before into two types corresponding to two different spawning times, but the author states that much more work is needed before the origin and migrations of the Cardigan Bay herrings can be definitely outlined.

W. C. H.

J. O. Borley. Distribution of the Food Fishes in the North Sea during 1923 & 1924 with Notes on the Natural History of the Food Fishes of the North Sea by D. E. Thursby-Pelham, Ministry of Agriculture & Fisheries, Fishery Investigations. Series II, vol. IX, Nr. 4. London 1926.

Unter diesem Titel erscheint eine beachtenswerte Arbeit, in welcher auf 45 Karten graphische Darstellungen von der Intensität der britischen Trawlfischerei in den Jahren 1923 und 1924 gegeben werden, während der erläuternde Text von J. O. Borley auf $1^1/_2$, der von D. E. Thursby-Pelham auf etwa 9 Seiten sich zusammendrängt.

Es ist also nicht die gesamte britische Nordseefischerei, die hier nach der speziellen Örtlichkeit und Größe ihrer Erträge kartiert wird, sondern nur der Fang von Bodenfischen, und auch an diesen nur, soweit er vom Trawl — nicht aber von der Angelfischerei — erfaßt wird; dagegen sind die Ergebnisse der Treibnetzfischerei überhaupt nicht berücksichtigt, und für den wichtigsten aller Nordseefische, den Hering, erhält man demnach kein zulängliches Bild in der gedachten Richtung, da der britische Trawlheringsfang im Verhältnis zum Gesamtheringsfang von verschwindend geringer Bedeutung ist; etwas günstiger liegen die Verhältnisse für die Makrele, da die britischen Trawlmakrelenfänge in den letzten Jahren ganz erheblich zugenommen haben; dagegen mußten einige Fischarten wie Sprott, Sardelle, u. a. unwichtigere ganz fortfallen, da sie niemals im Trawl gefangen werden.

Immerhin erstrecken sich trotz dieser Auslassungen die gegebenen Daten auf einen sehr großen Prozentsatz der Gesamtanlandungen von Nutzfischen in den Nordseeländern, denn diese betrugen im Jahre 1922 fast 475 Millionen Kg., und davon entfielen 68 % auf britische Schiffe.

Die Bewältigung dieser großen Arbeit war nur möglich, weil gewisse Vorbedingungen erfüllt waren. Unter diesen steht obenan die hervorragende Entwicklung der britischen Fischereistatistik, welche unter Aufwendung sehr bedeutender finanzieller Mittel die Fänge aller sogenannten erstklassigen britischen Trawler an den Märkten nach Gewicht der einzelnen Fischsorten, Dauer des Fischens während jeder einzelnen Reise in Trawlstunden und genauer Feststellung des Fangortes erfaßt. Für die letztere wird nicht mehr wie früher die Angabe der international vereinbarten Areas oder Tiefenzonen als ausreichend angesehen, sondern die Benennung einzelner Rechtecke (rectangles) von einem Längengrad und $^1/_2$ Breitengrad Seitenlänge verlangt, welche durch die Kombination von

Buchstaben (*A* bis *N*) für die Längen und von Zahlen (1—20) für die Breiten bezeichnet werden und eine mittlere Größe von 1350 Quadratmeilen haben.

In anderen Ländern sind derartig spezialisierte Angaben für die Fangstatistik nicht angestrebt worden, und es wird vielfach bezweifelt, ob die damit verbundenen hohen Ansprüche an die Willfährigkeit und Zuverlässigkeit der Schiffsführer überhaupt erfüllbar sind und nicht vielmehr zu willkürlichen Angaben Anlaß geben. Die britischen Sachverständigen glauben jedoch, daß diese Daten vollkommen genau und zuverlässig sind.

Eine weitere Vorbedingung für die Erfüllung der Aufgabe war der Umstand, daß für das Jahr 1923 zum ersten Male die statistischen Daten über den Fang von Bodenfischen durch erstklassige Dampftrawler für England und Schottland kombiniert wurden, so daß das Jahr 1923 als Anfangstermin für die vorliegenden graphischen Darstellungen gewählt werden konnte, die in Zukunft ihre Fortsetzung und Wiederholung finden sollen. Gerade dadurch ist zu erwarten, daß diese Kartierungen einen hohen Grad von Information über die bestehenden Verhältnisse in ihrer Regelmäßigkeit erhalten und daß zufällige und vereinzelte Vorkomnisse mehr und mehr ausgeschaltet werden.

Die vorliegende Publikation ist also als ein erster Versuch zu werten und verdient als solcher volle Würdigung und Anerkennung, und es erübrigt sich, allzu weit auf Einzelheiten einzugehen, die vielleicht einer Kritik zugänglich sind.

Nur einiges sei bemerkt. Da die Verfasser frühere ähnliche Versuche, über die Verteilung gewisser Fischarten in der Nordsee Klarheit zu gewinnen, nirgends erwähnen, so könnte es scheinen, als ob dergleichen bisher niemals versucht worden wäre. Das ist jedoch ein Irrtum. Es sei nur an die wiederholten Berichte (1—3) von D'Arcy Thompson und A. T. Masterman über die älteren Stadien der Gadiden und Pleuronectiden erinnert [vol. XII, XIII u. XIV der Rapp. et Proc. Verbaux (1910—1912)], Berichte, die in ihren graphischen Darstellungen ein recht klares Bild von der Verteilung der verschiedenen Fischarten in der Nordsee und von der Abstufung der Fangmengen geben. Das Verfahren dieser Autoren fußte auf der damaligen einfacheren Form der Fangstatistik, aber es hat doch schon damals im Großen und Ganzen zutreffende Bilder von der Verteilung der Nutzfische gegeben.

In der Einfachheit und Übersichtlichkeit können sich Borleys Darstellungen mit jenen nicht messen und deshalb gewinnt man einstweilen nicht den Eindruck, daß man sich mit Borleys Karten auf festerem Boden befindet. Dazu sind die Unterschiede zwischen den beiden einanderfelgenden Jahren 1923 und 1924 zu groß. Vielleicht kann aber die moderne Statistik, wenn sie für den vorliegenden Zweck besser ist, dazu benutzt werden, die früher gewonnenen Erfahrungen zu vertiefen und zu vervollständigen.

Auch die Aufzeichnungen von D. E. Thursby-Pelham über die Naturgeschichte der einzelnen Nutzfische der Nordsee stellen eine sehr dankenswerte populär gehaltene Zusammenfassung unserer Kenntnisse von diesen Fischen dar und geben namentlich für einige der wichtigsten Formen, wie Schellfisch, Kabeljau, Scholle u. a. ein sehr vollständiges Bild. Für viele

andere Formen wird sich durch Vermehrung des Beobachtungsmaterials den gegebenen Darstellungen manch wertvoller neuer Zug hinzufügen lassen.

Eh.

W. R. G. Atkins. The Phosphate Content of Fresh and Salt Waters in its Relationship to the Growth of the Algal Plankton, Journal Mar. Biol. Assoc., (1923), N. S. XIII, 119—150; Ibid. (1925), N. S. XIII, 700—720; Ibid. (1926), N. S. XIV, 447—467.

Prior to the work of Atkins and of Matthews, the determination of phosphorus in natural waters had fallen somewhat into disrepute, owing partly to the minute and apparently insignificant amount usually present and partly to the difficulties of technique and consequent uncertainty of the results.

Using the colorimetric method of Denigès, Dr. Atkins has reduced the determination of phosphate to a rapid and simple operation, accurate to $\pm$ 0.001 mg. per litre, and requiring a sample of only 100 cc. of water. It is essential in this, as in many other analytical methods, to carry out the determination as soon as possible after collection of the samples, as delay may lead to either increase or decrease of the apparent phosphate concentration — the former by disintegration of minute organisms and solution of the glass, the latter by bacterial metabolism. Numerous estimations of phosphorus have been made, on both fresh and sea waters, and much light has been thrown upon the rôle of this element in the annual cycle of algal metabolism and upon the seasonal variations in its concentration in the sea.

The phosphate content of a diatom culture was followed, until all the phosphate was used up. It was ascertained that 1 gm. of $P_2O_5$ is required, during the initial stages of vigorous growth, for the production of $9 \times 10^{11}$ diatoms (*Nitzschia closterium*). The vernal diminution in phosphate content affords a means of estimating the organic production of a given column of sea water, and the result obtained, though admittedly based on certain assumptions, is in remarkable agreement with that deduced from alkalinity values, viz. 1.4 kg. of algal plankton per square metre of sea surface, the plankton being distributed throughout the 70-metre column in which photosynthesis may be supposed to occur.

Determinations made over a series of years, at the International Hydrographic Stations on the lines "E" and "N" in the English Channel Area, show very definitely that the phosphate content of the sea water is at a maximum (about 0.036 mg. per litre) in winter, falling to a minimal value (almost zero) in the late spring and early summer, in evident relation to the varying abundance of the algal plankton. These values are very close to those of Matthews, obtained at a neighbouring station, but by a different method; another series, from the North Sea, while showing the same general seasonal trend, and agreeing so far with Raben, differs rather widely in its numerical values from the results of that investigator. The annual cycle is completed by the disintegration of plant and animal remains at the approach of winter, restoring the phosphate content of the

surface waters to the original level, but quite apart from this seasonal and superficial cycle, there is abundant evidence, from each of the great oceans, that the deeper waters, containing 0.05—0.08 mg. $P_2O_5$ per litre, form a great reserve of phosphate, which may become available when brought to the surface by upwelling currents.

The concentration of phosphate, given adequate illumination, is shown to be a limiting factor to plant-growth. Silica never appears to be completely exhausted, but nitrate and phosphate may, and in fact not infrequently do, reach the zero level, in the surface layers. Under these conditions, plant growth, and therefore animal growth, must cease, until seasonal or other changes restore the balance. Tropical seas, highly insolated even in winter, show a less marked rhythm of phosphate content than those of temperate zones, while in arctic latitudes, the seasonal phosphate variation is greater, leading to a very abundant summer development of the phytoplankton. J. R. B.

# Current Bibliography.

Prepared by the Editor.

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NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. ALLEN's Selected Bibliography published in Nos. 1 and 2 of the Journal, and since reprinted.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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